FOR·THE·INCREASE·AND·DIFFVSION·OF·KNOWLEDGE·AMONG·MEN·

PER ORBEM

·SMITHSONIAN·INSTITVTION·WASHINGTON·1846·

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43D CONGRESS, 1st Session. } SENATE. { MIS. DOC. No. 130.

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR 1873.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1874.

IN THE SENATE OF THE UNITED STATES,
February 13, 1874.

Ordered, That the annual report of the Regents of the Smithsonian Institution for the year 1873 be printed.

Attest:

GEO. C. GORHAM,
Secretary of the Senate.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

TRANSMITTING

The annual report of the Smithsonian Institution for the year 1873.

SMITHSONIAN INSTITUTION,
Washington, February 13, 1874.

SIR: In behalf of the Board of Regents, I have the honor to submit to the Congress of the United States the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1873.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. M. H. CARPENTER,
President of the Senate.

Hon. J. G. BLAINE,
Speaker of the House of Representatives.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR 1873.

This document contains: 1. The programme of organization of the Smithsonian Institution. 2. The annual report of the Secretary, giving an account of the operations and condition of the establishment for the year 1873, with the statistics of collections, exchanges, meteorology, &c. 3. The report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, the receipts and expenditures for the year 1873, and the estimates for 1874. 4. The proceedings of the Board of Regents. 5. A general appendix, consisting principally of reports of lectures, translations from foreign journals of articles not generally accessible, but of interest to meteorologists, correspondents of the Institution, teachers, and others interested in the promotion of knowledge.

OFFICERS OF THE INSTITUTION.

JOSEPH HENRY, SECRETARY,

Director of the Institution.

SPENCER F. BAIRD,

Assistant Secretary.

WILLIAM J. RHEES,

Chief Clerk.

DANIEL LEECH,

Corresponding Clerk.

CLARENCE B. YOUNG,

Book-keeper.

HERMANN DIEBITSCH,

Exchange Clerk.

JANE A. TURNER,

Exchange Clerk.

SOLOMON G. BROWN,

Transportation Clerk.

JOSEPH HERRON,

Janitor.

THE SMITHSONIAN INSTITUTION.

ULYSSES S. GRANT.......President of the United States, *ex-officio* Presiding Officer of the Institution
MORRISON R. WAITE...Chief-Justice of the United States, Chancellor of the Institution, President of the Board of Regents.
JOSEPH HENRY.........Secretary (or Director) of the Institution.

REGENTS OF THE INSTITUTION.

MORRISON R. WAITE...Chief-Justice of the United States, *President of the Board.*
HENRY WILSON ....Vice-President of the United States.
H. HAMLIN................Member of the Senate of the United States.
J. W. STEVENSON ......Member of the Senate of the United States.
A. A. SARGENT...........Member of the Senate of the United States.
S. S. COX...................Member of the House of Representatives.
E. R. HOAR.................Member of the House of Representatives.
G. W. HAZELTON.......Member of the House of Representatives.
JOHN MACLEAN ....Citizen of New Jersey.
PETER PARKER ....Citizen of Washington.
WILLIAM T. SHERMAN..Citizen of Washington.
ASA GRAY.................Citizen of Massachusetts.
J. D. DANA................Citizen of Connecticut.
HENRY COPPEE.........Citizen of Pennsylvania.

EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS.

PETER PARKER. JOHN MACLEAN. WILLIAM T. SHERMAN.

MEMBERS EX-OFFICIO OF THE INSTITUTION.

U. S. GRANT. ....President of the United States.
HENRY WILSON ....Vice-President of the United States.
M. R. WAITE ....Chief-Justice of the United States.
H. FISH ....Secretary of State.
B. H. BRISTOW...........Secretary of the Treasury.
W. W. BELKNAP ....Secretary of War.
G. M. ROBESON...........Secretary of the Navy.
J. A. J. CRESWELL ......Postmaster-General.
C. DELANO.................Secretary of the Interior.
GEO. H. WILLIAMS......Attorney-General.
M. D. LEGGETT..........Commissioner of Patents.

REPORT OF THE SECRETARY, PROFESSOR HENRY, FOR THE YEAR 1873.

GENTLEMEN: I have the honor herewith to present a continuation of the history of the Smithsonian Institution, comprising an account of its operations, condition, and expenditures during the year 1873. No change in this time has been made in the general policy of the establishment. Congress has continued its appropriations for the support of the National Museum under the charge of the Institution, and has thus relieved the Smithson fund from a burden the support of which has annually absorbed a large portion of the income. Freed from the expense of the support of the museum, at the beginning of 1873 we anticipated doing much more than we had previously done in the way of advancing science without encroaching on the unexpended balance in the Treasury at the close of 1872, but in this we were disappointed by the failure of the First National Bank of Washington, which had in its possession at the time of its suspension a considerable portion of the semi-annual income received on the 1st of July, and which was intended to carry on our operations during the remainder of the year. Previous to 1867 the interest on the Smithson fund was deposited in the private banking house of Riggs & Co., but at the session of the Board February 22, 1867, I was directed, by a resolution suggested by Chief Justice Chase, to transfer the money to the First National Bank, an authorized Government depository. This was accordingly done, and the bank faithfully discharged the duty which devolved upon it until the 19th of September, 1873, when it failed to honor our drafts. The whole sum in the bank at this time was $8,224.87. On this sum the Institution has since received a dividend of 30 per cent., amounting to $2,467.46. In order to meet this unexpected difficulty a reduction was made, as far as possible, in the accruing expenses, by stopping the printing of various articles, and deferring for a time the prosecution of various enterprises in which the Institution had previously embarked.

For paying the salaries and other urgent claims an application was made to the Secretary of the Treasury to advance the quarter-yearly interest which had accrued on the 1st of October. To this application the Secretary, Mr. Richardson, gave due attention, and expressed his willingness to grant the favor provided it could be done in accordance with law. It was, however, decided by the comptroller that the interest could only be paid semi-annually, as prescribed by the act organizing the Institution.

Disappointed in obtaining relief from this source, an appeal was made to Mr. G. W. Riggs to advance what might be required to pay the necessary expenses of the establishment during the remainder of the year. This he promptly consented to do at a time when loans of money could scarcely be obtained unless at the most exorbitant rates; and this, too, without charge for interest. Such liberality could scarcely have been expected, especially after the deposits had previously been withdrawn from Mr. Riggs on the plea of greater security.

To relieve the Board of Regents and the secretary in future from all anxiety as to the safety of the semi-annual interest, I would advise that hereafter it be placed in charge of the Treasurer of the United States. I am informed that he is authorized to receive on deposit, from officers of the Army and Navy, money which has been appropriated by Congress to special objects, and as the Smithson income is the proceeds of a sacred trust committed to the Government of the United States, the same privilege should be, and I doubt not would be, extended to it.

The Smithson fund since the war has been much diminished in efficiency by the inflation of the currency, and the consequent high price of labor and materials. It is true that the Government pays the Institution in gold, but the premium on this is by no means an equivalent for the diminution of purchasing power of the money received: since paper has been substituted as a legal tender, gold itself has become an article of commerce, the price of which depends on the supply and demand. While the premium on gold is, say, ten per cent., the difference of prices due to inflation is, in many cases, a hundred per cent. In addition to the effect of the diminution of the value of the Smithson fund by the inflation of the Government currency, is that of the gradual inflation of the currency of the world by the products of the mines of California and Australia. It is estimated that this, during the last twenty-five years, has made a difference in prices throughout Europe and this country equivalent to twenty per cent.

To keep up, therefore, the efficiency of the Smithson fund in the way of producing new results in intellectual labor, it was necessary that additions should be made to it; and from the following financial exhibit, and those which have been shown in preceding reports, it is evident that this consideration has received proper attention.

The following is a statement of the condition of the funds at the end of 1873 or the beginning of 1874:

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States, in accordance with the act of Congress of August 10, 1846	$515,169 00
The residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States, in accordance with the act of Congress of February 8, 1867	26,210 63
Total bequest of Smithson	541,379 63

Amount deposited in the Treasury of the United States, as authorized by act of Congress of February 8, 1867, derived from savings of income and increase in value of investments	$108,620 37
Total permanent Smithson fund in the Treasury of the United States, bearing interest at 6 per cent., payable semi-annually in gold	650,000 00
In addition to the above, there remains of the extra fund from savings, &c., in Virginia bonds and certificates, viz: Consolidated bonds, $58,700; deferred certificates, $29,305.07—now valued at	33,000 00
Cash balance in United States Treasury at the beginning of the year 1874, as a special deposit for current expenses	12,226 68
Amount due from First National Bank, $5,757.41, (present value unknown.)	
Total Smithson funds January, 1874	695,226 68

PUBLICATIONS.

Since the reports of the Institution are separately distributed to individuals who have not immediate access to the whole series, it is necessary in each to repeat certain facts which may serve to give an independent idea of the general organization of the establishment. For this purpose the following statement is repeated in regard to the publications:

The publications of the Institution are of three classes—the Contributions to Knowledge, the Miscellaneous Collections, and the Annual Reports. The first consist of memoirs containing positive additions to science resting on original research, and which are generally the result of investigations to which the Institution has in some way rendered assistance. The miscellaneous collections are composed of works intended to facilitate the study of branches of natural history, meteorology, &c., and are designed especially to induce individuals to engage in studies as specialties. The annual reports, beside an account of the operations, expenditures, and condition of the Institution, contain translations from works not generally accessible to American students, reports of lectures, extracts from correspondence, etc.

The following are the rules which have been adopted for the distribution of the publications of the Smithsonian Institution:

1st. To learned societies of the first class which present complete series of their publications to the Institution.

2d. To libraries of the first class which give in exchange their catalogues and other publications, or an equivalent from their duplicate volumes.

3d. To colleges of the first class which furnish meteorological observations, catalogues of their libraries and of their students, and all other publications relative to their organization and history.

4th. To States and Territories, provided they give in return copies of all documents published under their authority.

5th. To public libraries in this country, not included in any of the foregoing classes, containing 15,000 volumes, especially if no other copies are given in the same place, and to smaller libraries where a large district would be otherwise unsupplied.

6th. To institutions devoted exclusively to the promotion of particular branches of knowledge are given such Smithsonian publications as relate to their respective objects.

7th. The reports are presented to the meteorological observers, to contributors of valuable material to the library or collections, and to persons engaged in special scientific research.

The distribution of the publications of the Institution is a matter which requires much care and a judicious selection, the great object being to make known to the world the truths which may result from the expenditure of the Smithson fund. For this purpose the principal class of publications, namely, the Contributions, must be so distributed as to be accessible to the greatest number of readers, and this will evidently be to principal libraries.

The volumes of Contributions are presented to institutions on the express condition that, while they are carefully preserved, they shall be accessible at all times to students and others who may desire to consult them. These works, it must be recollected, are not of a popular character, but require profound study to fully understand them; they are, however, of immense importance to the teacher and the popular expounder of science. They contain materials from which general treatises on special subjects are elaborated.

Full sets of the publications cannot be given to all who apply for them, since this is impossible with the limited income of the Institution; and, indeed, if care be not exercised in the distribution, so large a portion of the income will be annually expended on the production of copies for distribution of what has already been published that nothing further can be done in the way of new publications. It must be recollected that every addition to the list of distribution not only involves the giving of the publications which have already been made, but also of those which are to be made hereafter.

At the commencement of the operations of the Institution the publications were not stereotyped, and consequently the earlier volumes have now become scarce, especially the first, of which there are no copies for distribution, although it can occasionally be obtained at a second-hand book-stall in one of the larger cities.

No copyright has ever been secured on any of the publications of the Institution. They are left free to be used by compilers of books, without any restrictions except that full credit shall be given to the name of Smithson for any extracts which may be made from them.

This condition is especially insisted on, because the credit thus required is an important evidence to the world of the proper management of the Smithson fund.

Publications in 1873.—During the past year the eighteenth volume of the quarto series of the Smithsonian Contributions to Knowledge has been published. The several parts of this volume have been described in previous reports. It contains the following papers:

I. Tables and results of the precipitation in rain and snow in the United States, and at some stations in adjacent parts of North America, and in Central and South America. Collected by the Smithsonian Institution, and discussed under direction of Joseph Henry, Secretary. By Charles A. Schott, 4to., pp. 178, eight diagrams, five plates and three charts.

II. Memoir on the secular variations of the elements of the orbits of the eight principal planets, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune, with tables of the same. Together with the obliquity of the ecliptic, and the precession of the equinoxes in both longitude and right ascension. By John N. Stockwell, M. A., 4to., pp. 214.

III. Observations on terrestrial magnetism and on the deviations of the compasses of the United States iron-clad Monadnock during her cruise from Philadelphia to San Francisco, in 1865 and 1866. By Wm. Harkness, M. D., 4to., pp. 225, with two diagrams.

IV. Converging series expressing the ratio between the diameter and the circumference of a circle. By William Ferrel, 4to., pp. 6.

This volume consists of 643 pages, and is illustrated by five plates, three large double charts, and numerous diagrams. The distribution of this volume to foreign societies has been nearly completed. As in the case of the preceding volumes, it will tend to perpetuate the name of Smithson conspicuously in the records of the history of science, and will thus form a more befitting monument to his memory than one of marble or of bronze.

One of the memoirs accepted for future publication in the Contributions is on the Lucernaria, by Professor Henry J. Clark. This memoir relates to a class of animals which are more or less octagonal, bell-shaped, or rather inverted umbrella-like, with tentacles clustered in groups at the eight angles. They were in former times regarded as a group of the polyps, that is, related to the sea-anemones, but in more recent times have been associated with the Acalephs or sea-nettles and jelly-fishes, and either combined with one of the more comprehensive orders, or regarded as the representatives of a peculiar one. Such is the group which has been the subject of Professor Clark's latest studies, and which is considered by him as entitled to ordinal rank in the class of Acalephs.

His work is divided into two parts; the first devoted to the "general and comparative morphology," and the second restricted to the "anatomy

and physiology of *haliclystus auricula*." In the first part are three chapters; the first on "individuality," in which are considered the questions relating to "polarity and polycephalism" and "the hydroid and medusoid cephalisms." In the second the thesis that "the type of form is not radiate" is defended, and the form is described as "the dorso-ventrally repetitive type." The third chapter is devoted to the consideration of "antero-posterior (cephalo-caudal) repetition," and under the heads of "the scyphostoma and ephyra varieties of the same morph" and "the individuality of Pelagia and Lucernariæ."

In the second part are four chapters, the third to seventh of the entire work. In the first (third of the work) are described the "general form and structure," including habitat, habits, form, and size, the proboscis, the umbella, and the peduncle. In the second is considered the "organography, including the walls," "the muscular system," "the tentacles, the marginal adhesive bodies, or collecystophora," "the caudal adherent disc," "the digitiform bodies, or digitali," "the digestive system," "the nervous system," and "the reproductive system."

In a third are embraced the results of studies of the "embryology," or various stages of growth of the species, including observations on "the egg and the spermatozoa;" on "a young *haliclystus auricula*, nearly one-sixteenth of an inch in diameter;" on "a specimen three thirty-seconds of an inch across the umbella;" on "a young specimen one-eighth of an inch across;" on the "special development of a tentacle, a colletocystophore, and a genital sac;" on the "young one-fifth of an inch across;" and on the "young six twenty-fifths of an inch across."

In a fourth chapter the tissues are considered in a "histology of *haliclystus auricula*" and in the several parts of the body—that is, "the umbellar and peduncular walls;" "histology of the tentacles;" "histology of the collectocystophores," (anchors;) "histology of the caudal disc;" and "histology of the digitali" and "the prehensile cysts," (nematocysts and colletocysts.)

This enumeration of the chapters and their sections will furnish to the naturalist an adequate idea of the mode of treatment of the subject as well as of the different organs and parts represented in the animals. It will suffice to add that the several parts are treated of in great detail, and are illustrated in eleven quarto plates from drawings by the author.

The plates for this memoir are in the process of being engraved, and the work will be published as soon as the funds of the Institution will permit. We have to regret, since the work was adopted by the Institution, that the author has been called from this life in the flower of his age and the promise of many days of successful devotion to science.

The next memoir accepted for publication, and which will probably form the whole of the twentieth volume of the Contributions to Knowledge, is by Joseph Jones, M. D., professor of chemistry and clinical medicine in the University of Louisiana. It gives the results of a very extended in-

vestigation of the military, religious, monumental, and organic remains of the ancient inhabitants of Tennessee. An appropriation was made to assist Dr. Jones in an exploration of these ancient remains, and to this work he has devoted an immense amount of labor. The results are presented in a volume which, after considerable abridgment, still consists of over 600 folio manuscript pages, requiring about two hundred wood-cuts and a number of plates for its illustration. The work was submitted to Dr. Otis, of the Army Medical Museum, who has given special attention to the subject of ethnology, and on his approval it has been accepted for publication. We think it is a valuable addition to our knowledge of the ancient races which have inhabited this continent, and well worthy of a place in the Smithsonian series of Contributions. The following extract is made from the preface by the author:

"The explorations and researches were commenced in the early part of 1868, and continued to the close of 1869. In the entire investigation, and in presenting an outline of the explorations and researches, I have endeavored to accomplish two results, viz: the accurate description of the aboriginal remains, and the collection of facts which bear in any manner upon the obscure history of the ancient inhabitants of this region. With the limited means at my command, and with numerous pressing professional duties and cares, I was unable to carry forward the explorations upon the scale which their importance appeared to demand, but it is earnestly hoped that these investigations, however imperfect, will be found an addition to knowledge which may serve as a point of departure for future explorers in this interesting field. They will not be without practical result if they should serve to form a basis for the comparison of the crania and works of art of the races of the stone-age of Tennessee and Kentucky with those of other parts of our country and of foreign climes."

The following is a brief abstract of the contents of the work:

Chapter I.—Inquiries regarding the name and history of the ancient race which inhabited in past ages the fertile valleys of Tennessee and Kentucky, called by early explorers the Chaöuanins.

Chapter II.—Ancient cemeteries. The so-called "mummies" discovered in caves. Mode of burial practiced. Stone graves. Inquiry into burial customs of the Indians.

Chapter III.—Mounds, fortifications, and earth-works.

Chapter IV.—Sites of aboriginal towns or encampments surrounded by earth-works. Description of contents of mounds. Indian traditions. Relations of early explorers and missionaries to the aborigines.

Chapter V.—Works of art, religious relics, sculptures, paintings, implements, weapons, vases, culinary vessels, idols, shell ornaments.

Chapter VI.—Crania of the mound-builders—comparisons with those from Mexico, Europe, &c. Discussion of the causes which led to the rapid depopulation of the American continent after its discovery by Columbus. General conclusions.

Another paper intended for the Contributions is on the Haida Indians of Queen Charlotte's Islands, by James G. Swan. These islands consist of a group in the Pacific Ocean, lying off the northwest coast of America, seventy-five miles northwest from Vancouver's Island, and at a distance from the main-land varying from sixty to a hundred miles. They are inhabited by a tribe of Indians who in manners and customs are somewhat different from the neighboring tribes on the main-land and from those of Vancouver's Island. In general appearance they resemble the natives of the northwest coast of Asia. Their distinctive features are apparent to the most casual observer. They are as a general rule of large stature, with better proportions and lighter complexion than the Selish tribe of Flatheads, inhabiting Washington Territory and British Columbia. This difference is particularly marked among the females. Those of the Haida tribe are tall and athletic, while the Selish women are shorter, with a greater tendency to corpulency. These people are especially distinguished for their carvings in stone and wood, and also for their tattooing.

The memoir is illustrated with drawings of specimens of these carvings, some of which are colored, and also with samples of tattooing, the latter copied by photography from the bodies of the Indians themselves. Some of the carvings represent posts or pillars placed in front of the houses of the chiefs, and are sometimes from 40 to 50 feet high. They are not intended as objects of worship, but as representations of the "toten" or heraldic insignia of the family occupying the house before which they are erected. As the house generally contains several families, the carving may be said to indicate the family names of all the occupants. It is important to state that these carvings have a general likeness to those found in Central America.

The paper will be an interesting addition to ethnology, as affording data for the comparison of the imitative art among the present and extinct races along the Pacific coast of America. It is by the author of the work on the Makah Indians, of Cape Flattery, published not long since by the Smithsonian Institution.

Besides the eighteenth volume of Contributions to Knowledge, the tenth volume of Miscellaneous Collections has been published. It consists of 913 octavo pages, and contains the following articles:

I. The Mollusks of Western North America; by Philip P. Carpenter, B. A., Ph. D., embracing the second report made to the British Association on this subject, with other papers; reprinted by permission, with a general index; pp. 446.

II. Arrangement of the families of Mollusks; prepared for the Smithsonian Institution by Theodore Gill, M. D., Ph. D., pp. 65.

III. Instructions for observations of thunder-storms, by Prof. Joseph Henry, p. 1.

IV. Circular relative to heights; by Prof. Joseph Henry, pp. 2.

V. Directions for constructing lightning-rods; by Prof. Joseph Henry, pp. 3.

VI. Queries relative to tornadoes; by Prof. Joseph Henry, pp. 4.

VII. Questions relative to the food-fishes of the United States; by Prof. S. F. Baird, pp. 7.

VIII. Memoranda of inquiry relative to the food-fishes of the United States; by Prof. S. F. Baird, pp. 5.

IX. List of the institutions, libraries, colleges, and other establishments in the United States in correspondence with the Smithsonian Institution, pp. 255.

X. List of Foreign Correspondents of the Smithsonian Institution, corrected to January, 1872, (fourth edition,) pp. 96.

XI. Check-List of Publications of the Smithsonian Institution, pp. 22.

The first article in this volume having not previously been described, the following account of it will here be properly in place. It is one of the series published by the Institution for facilitating the study of certain branches of the natural history of North America. It may be recollected that Mr. Philip P. Carpenter, a distinguished conchologist of England, when visiting the United States in 1859–'60, was engaged by the Institution to arrange and name the shells collected by the United States exploring expedition and those collected by other parties on the Pacific coast of North America. Mr. Carpenter had previously presented to the British Association a report on the Mollusks of the west coast of North America. On his return to England he made, to the same society, a supplementary report on this subject, embracing materials principally derived from the Smithsonian Institution. In order to facilitate the study of this class of animals by the American student, the reports in question and other materials have been reprinted from the stereotype plates of the British Association, kindly furnished the Institution for this purpose.

The propriety of this publication by the Smithson fund will be evident when it is stated that the materials on which it is founded are chiefly in the collection of the National Museum, under the charge of the Institution, and the report of the British Association forms a series of volumes which cannot be purchased separately, and are therefore inaccessible to the working naturalists of this country, to whom the work is more especially important.

"The principal object in preparing the works," says Mr. Carpenter, "is to collect and compare the writings of previous naturalists, so that it might be possible for students to commence where I leave off without being obliged to waste so large an amount of time as I have been compelled to do in analyzing the works of their predecessors." To render this work more useful an index has been prepared at the expense of the Institution, which, besides its importance to the general student of conchology, will be of special advantage to those who desire to study the specimens in the national museum. This work will be a valuable addi-

tion to the literature of zoology, and will fill a void in the descriptive history of the mollusca of this country. One of its chief merits is that in it are collected together from many sources notices of the labors of all previous investigators, and in many cases extracts of all that is important from their works. How much the publication of such monographs has tended to the advancement and acceleration of our knowledge of any group, the past history of zoology amply shows.

Another article in this volume not previously described is that drawn up by Professor Baird relative to inquiries as to the food-fishes of the United States. It has been used by him in his capacity of United States fish commissioner, but will be useful for reference to all who may be interested in this subject. The questions relate to the names, distribution, abundance, size, migration, relationship, food, reproduction, culture, protection, disease, capture, and value of fishes.

The circular on lightning-rods was prepared to save time in answering the frequent inquiries as to the best means of protection from lightning. On this subject it is proper to remark that the country is overrun with patented inventions for alleged improvements in lightning conductors. Most of these are founded on misconceptions of established principles of electricity, and although they may in most cases, if properly connected with the earth, serve to conduct a discharge which would otherwise be attended by serious consequences, harmlessly to the ground, yet they do not possess the character as to improvements which is claimed for them by their vendors.

The instructions for observations on thunder-storms originated in the desire to obtain special information as to the origin, direction of movement, and other facts relative to these interesting meteors, which are intimately connected with tornadoes. The latter phenomenon occurs, perhaps, more frequently in the United States than in any other country, and from the devastations which attend its progress over the surface of the earth, it becomes an object worthy of attention of the public generally as well as the professed meteorologist.

Another publication forming a portion of the Miscellaneous Collections is the third and completing part of a series of monographs of the Diptera, or two-winged insects, of North America, by Baron Osten Sacken, late of the Russian legation, and Dr. H. Loew, of Prussia. The first part was published in 1862, and included the families of *Trypetidæ*, *Sciomyzidæ*, *Ephydrinidæ*, and *Cecidomyidæ*. The second part appeared in 1866, and consists principally of a monograph of the *Dolichopodidæ*. The fourth part was issued in 1869, and embraces a monograph of part of the *Tipulidæ*. The third part, or that in question, includes the families of the *Ortalidæ* and *Trypetinæ*. In variety of forms, says the author, the family of *Ortalidæ* is scarcely surpassed by any other Diptera; at the same time it is hardly equaled by any in the structural differences occurring among the

individuals. Hence, it may be considered as one of the most interesting families of the order. Nevertheless, but little has been done as yet for the exact definition of its limits nor for its subdivision into smaller groups. It was, therefore, impossible to attempt a satisfactory description of the North American species of the *Ortalidæ* without first settling the question of the true limits of the family, of the relationship of it to other families, and of the character upon which it is established. This preliminary work the author thinks he has successfully accomplished, and presents his reasons for this in an introductory chapter, in which is reviewed what has previously been done on this point.

The *Trypetidæ* given in this part of the general work may be considered as a supplement to that published on the same family in the first part of the series. This supplement has been rendered necessary by the number of species of the family which have been found since the date above mentioned. At that period only twenty-three North American species were known. Since then the number has reached sixty-one, besides a number of species of previous authors of which information has since been procured. The author has, therefore, adopted the form of a supplement to his previous paper.

The following remarks in regard to the series, are by Baron Osten Sacken:

"As this will probably be the last volume of the present series of the publication of which I have the care, a few words with regard to the use and aim of these volumes may not be out of place here. The diptera, from the minuteness of their size and the extreme delicacy of the characters upon which their classification is based, are without any doubt the most difficult to study of all the orders of insects. To the general difficulty of the subject, the North American diptera add another one in their analogies with the European fauna on the one side and the South American on the other. At the same time the dipterological literature in the English language is not a rich one. The only eminent English dipterist, Mr. Haliday, published so little that his superiority was known to his correspondents much more than to the public in general. Other English publications which exist are utterly insufficient for any scientific purpose, and more apt to mislead than to teach. Now the volumes of the Monographs, although they embrace but an inconsiderable fraction of the whole dipterous fauna of this continent, show at least how the subject has to be treated, how descriptions are to be drawn, what characters have to be noted, what analogies with the European and South American fauna occur, and with what care they have to be studied in order to distinguish analogy from identity. Moreover, three of those four volumes are the work of the first dipterologist now living, who, after Meigen, may be considered as the founder of scientific dipterology. For all these reasons, I hope that the labor and expense bestowed upon these publications will, after a time, bring its fruit, although it may not be immediately."

Another article intended for the Miscellaneous Collections is a synopsis of American vespidæ, or wasps, by Professor De Saussure, of Geneva, translated from the original manuscript by Mr. Edward Norton, of Farmington, Conn. This work was commenced a number of years ago, but owing to the absence of Mr. Norton from the country and other causes of delay, it was suspended and has only been resumed during the last year. It will now be completed as rapidly as the corrected proof-sheets can be received from Switzerland. The character of the work is given in the following extract from the introduction, which also contains suggestions as to the philosophy of points of natural history well worth the attention of the general students of this branch of science :

"I propose in this volume not to give a general history of the wasps of America, but only to lay the foundations of the fauna of the *vespidæ*, principally of North America. I leave aside whatever concerns the habits of these insects, on which we have but insufficient information, and shall confine myself to speaking of them with respect to the genera or species which shall offer me some salient peculiarities. This work is not to be taken for a mere catalogue of species, of no further use than to satisfy curiosity. I think that modern zoology ought to tend toward another aim. The existence of species, the composition of fauna, their relations with the parts of the globe which they inhabit, are not merely accidental facts. In my opinion we must therein detect the last material and tangible manifestation of physiological forces, the study of which belongs to the domain of the highest natural philosophy. By him who adopts this view of the subject a far-searching study of species ought to be considered as one of the bases from which the search after the origin of species may start.

"It would seem that in zoology we ought to take for a starting point the actual existing forms in which life manifests itself, to ascend thence up to the primitive stock, just as in geology we start from the actual existing structure of rocks, and from the external configuration of the soil follow up the concatenation of the ancient events which have brought about as a last result the present state of the earth's crust.

"The study of species ought especially to serve as a means of revealing to us their variations and the affinities between them. These affinities point to a common relationship which is to be explained only by a direct filiation of the types. The study of forms, combined with that of their geographical distribution, comes afterward to throw light on the cause of the filiation which the graduated resemblances of the species seem to reveal to us. It shows that this filiation obeys laws which have also their regularity in so far as they are intimately connected with the physical laws which hold sway in every region of our globe.

"Toward these grand philosophical questions zoology ought in our time to tend, and species ought to be studied with a view to the solution of such questions. As in geology the study of the actual existing

state of the earth's crust and the appreciation of the phenomena that there take place, of the intimate transformation of rocks, of the mechanical destruction of the layers, of their reconstruction under new forms, allows us to draw an inference by analogy as to the more ancient transformations and the agents which have produced them; so the study of species and of their actual existing transformations seems likely to enable us to follow up the chain of these transformations to a point more or less close to their origin. The definition of the first divergences observable in the permanent varieties, which may be considered as *nascent species*, in order to ascend afterward to the relationship of species separated by the divergences more and more profound, such is, we deem, the point of view under which we should never neglect to study species.

"Zoology only when considered from this point of view is philosophical. It has not its aim in itself; it serves only as a means to sift questions of a higher order. Now, entomology is precisely the one of the branches of zoology in which the study of the filiation of species may become the most fecund in results, either on account of the multitude of ramifications of general types and of the multiplicity of forms under which each type appears, or on account of the smallness of the breaks which separate genera and species, or also on account of the immense variety of forms and of the facility with which species seem to become modified in proportion as they spread over the surface of the globe in following diverging ways. Thanks to all these causes, it is not difficult to find examples of every kind of filiation; not difficult, either, to follow over latitudes certain modifications still recent which allow us to draw an inference by analogy as to other modifications more profound because they are more ancient, and as to others of a degree still more advanced.

"Unfortunately in our times the greater number of entomologists have deviated too far from this philosophical path. They have turned entomology into a sort of amusement, which has for its object the discovery of new species; which loses itself in minutiæ, and at the bottom of which there exists no thought. Thanks to this tendency, collecting has ceased to be the means, and has become the object. In becoming an amusement entomology has gradually lost caste; it has fallen into the hands of dawdlers, and thus lost a part of its scientific character. This transformation has led men who aim at reaching an elevated rank in science to be too much inclined to withdraw from the field of entomology.

"As may be anticipated from what precedes, my intimate purpose in producing this work is to study the American fauna with a view to its origin. But this is a work of time which cannot be completed off-hand. The first thing to be done is to study carefully the species, to arrange them according to a good classification, and to describe, while proceeding, their affinities. That is the fundamental preparatory labor. I have not the pretension to overstep those limits in this monograph.

The knowledge of the American fauna is not yet advanced enough to allow us to draw with certainty an inference as to the affinities of the species between them so as to prejudge their filiation. However, I have made more than one remark on this topic, and I will hazard a few words on the matter when speaking of genera and species. But I reserve for another work the statement of comparisons which seem to me to cast some light on the dispersion of the vespidæ on the surface of the globe and on the modifications which have been worked off under diverse latitudes; in other terms, on the origin of actual existing faunæ.

"The complex affinities of species, and still more the filiations which arise from these affinities, become obvious to the eye only when one has acquired a perfect knowledge of the species and genera of a fauna. To seize them in all their extent, it is necessary to know, as it were, all the species of the group by heart in order to be able to take it in at a glance, or to examine at pleasure each part in the picture that one has formed in one's memory. Only when one has attained this point in the study of the group is it possible from the inspection of a species to feel its affinities, for they do not always appear in the more easily appreciable characteristics. They often discover themselves in certain characteristics of appearance which are, at times, of great importance, but which are not seized at a glance, or in certain relationships of form, which a long practice teaches one to distinguish easily, though they can scarcely be defined.

"The first basis of philosophical zoology is the profound knowledge of the detail of faunæ. To give an idea as complete as possible of the faunæ of the VESPIDÆ of America is the purpose of this volume.

"The plan which I have decided on, in drawing up this work, is the following:

"I give as far as possible the complete description of the species which belong to the fauna of North America, considering as such all those which people the new continent to the north of the Isthmus of Panama, including likewise the Antilles. This work is, therefore, more especially a monograph of the vespidæ of the United States, of Mexico, and of the Antilles. Besides, I have added, as a complement, the catalogue of all the species known till now in the rest of America, and I have found it a great advantage for the classification, the method becoming thus more complete. Moreover, this plan allows me to enunciate views on the geography of insects, on the dispersion of the species, and on the modifications which take place under the influence of diverse latitudes.

"I have confined myself, for the species of South America, to making a catalogue of them, not having materials sufficient for a monograph. For those, however, of which I had the types under my eyes, I have given Latin diagnoses, in order to present them in a comparative manner with respect to the surrounding species and also to complete

my previous studies of these insects, as well as to resume them and render their use more easy.

"I think myself bound to add here that as to my method of description, I describe as much as possible the species in a relative manner. Descriptions made in an absolute sense have always appeared to me less useful, because they insist on many useless characteristics and omit often the most important. The reader will not, therefore, be surprised at my not repeating, with respect to genera, the characteristics proper to every species or to the greatest number. In short, there are still other characteristics which I pass over, considering them rather useless, either on account of their constancy (such as the presence of silky hairs on the tibiæ) or on account of their variableness, such as the color of the lower surface of the abdomen.

"Descriptions are often made tedious by means of these superfluous indications and thus the essential characteristics are drowned in useless developments. In this way, precision is impaired instead of being increased. Doubtless, here again nothing is absolute. Certain isolated species may be sufficiently characterized by some salient traits, while others, surrounded by very closely connected species, require minute descriptions.

"Absolute and very detailed descriptions ought, in my opinion, to be employed when one describes a species isolatedly without knowing the most closely connected types, (for instance in the publications of geographical expeditions.) It is the monographer's duty to eliminate from these descriptions both the common-place and the useless. But in a monograph, the species are to be examined in a comparative manner and relatively to the adjacent types.

"The first condition of good comparative diagnoses resides in a wise co-ordination of the species which by way of exclusion may lead to choosing only between a small number of species. Though I do not like to find fault, I cannot, however, on this score, help complaining of the works in which the species, though described in an absolute manner, (that is by themselves and not comparatively with others,) are jumbled up together, without order, without division of genera, often in defiance of the most salient characteristics.

"Such works, got up in a hurry, the plans of which are laid down with a view to the convenience of the authors and not for that of the readers, cause the latter to lose much valuable time with no great result. They do not come up to the precision now required by the progress of science, and they are, therefore, behind their time. The reader cannot occupy his mind with incomplete works, nor can he waste his time in striving to find out species which are not to be found out; for there is no doing impossibilities.

"In most of my descriptions I have been especially attentive to the forms and characteristics of the form and marking, attributing to the color only a secondary importance, on account of its frequent variable-

ness. However, there is nothing absolutely fixed in nature; the forms and the marking, likewise, vary within certain limits. Therefore, the descriptions can only be averages deduced from a certain number of individuals.

"Theoretically, the description ought to represent, as it were, the algebraical formula of the species or its ideal type. It is not required that the description should tally with the individual, but, on the contrary, that it should represent the average of the characteristics of the ensemble of individuals. But in practice the description can never be so perfect, since it is drawn from a certain number of individuals and not from the ensemble of the individuals that represent the species. It is for the reader to know how to seize the connection that exists between the description and the even heterogeneous individuals which he may have beneath his eye. In a word, my method of description aims above all at generalizing, and requires that the reader should generalize likewise. It cannot suit much the amateur inclined to lose himself in a multiplicity of details, for whom the collection takes the place of nature, and for whom the determination of an individual is the final purpose of the study of a species.

"From the principles just laid down it follows that, in the extreme subdivisions of genera, I have usually preferred the characteristics taken from the form to those taken from the color. Undoubtedly it is less convenient for the reader, for the natural method is always less easy to follow than the empirical system; nevertheless I think that it is preferable to proceed in that wise, for whatever may be done to seek the natural method a large portion of empiricism is sure to remain, as I shall endeavor to show, in the study concerning the filiation of the species. We cannot, therefore, eliminate too carefully from classification, empirical elements.

"It is necessary to observe on this head that no absolute rule can be laid down as to the insubordination of characteristics. To be sure, forms varying less than colors, they offer, in general, characteristics more important than the latter; but there is, however, now and then a case in which the colors are more fixed than certain forms, and assume a real importance; for instance, as being the stamp peculiar to a certain geographical zone. Thus, the division *Hypodynerus*, (genus *Odynerus*,) which depends greatly on the colors and facies, and which comprises the most divergent forms. In this case the livery becomes the casket of a fauna, and is very important. In the succession of species it is generally observed that the colors vary much even when the forms remain fixed (or vary less;) but there are other cases in which it is color that remains stationary while the forms vary."

In the Smithsonian report for 1858, a paper was published on the method of *collecting and preserving insects*, prepared by Baron Osten Sacken, of the Russian legation, with contributions by other eminent entomologists, which has rendered valuable service in the way of

awakening an interest in entomology, and in facilitating the collecting of specimens. It was, however, not stereotyped; and as the methods of gathering and preserving insects have been much improved since the date of its preparation, it has been thought advisable to request Dr. A. S. Packard, jr., a leading authority on entomology, to furnish a new treatise on the same subject. In compliance with this request he has prepared a work corresponding with the present state of our knowledge. This work was published during the past year, and forms an octavo pamphlet of 58 pages, with 55 illustrations.

Two other articles, which will form parts of the eleventh volume of the Miscellaneous Collections, and will constitute a part of the series for facilitating the study of certain branches of natural history, are a continuation of works previously prepared by Dr. John Le Conte, of Philadelphia, on the North American Coleoptera, and published by the Institution. One of these consists of a description of new species of coleoptera, described since the publication of the first work on the same subject, and the other a supplement of the "Classification of the coleoptera of North America." The object of these works, as far as they relate to the genera of coleoptera, is to enable those who have a desire beyond that of merely collecting specimens to acquire sufficient information to enable them to consult with profit the various works in which are contained the descriptions of the species. The parts now printed comprise one hundred and forty pages, and will be followed by other supplements, descriptive of such other species as may be obtained from Smithsonian collaborators and other sources.

In the report for 1856, is given a plan by the late Mr. Charles Babbage, of London, of a series of tables to be entitled the "Constants of Nature and Art." These tables were to contain all the facts which can be expressed by numbers, in the various sciences and arts, such as the atomic weight of bodies, specific gravity, elasticity, specific heat, conducting power, melting point, weight of different gases, liquids, and solids, strength of different materials, velocity of sound, of cannon-balls, of electricity, of light, of flight of birds and speed of animals, list of refractive indices, dispersive indices, polarizing angles, &c.

The value of such a work, as an aid to original investigation, as well as in the application of science to the useful arts, can scarcely be estimated. To carry out the idea fully, however, would require much labor and perhaps the united effort of different institutions and individuals, devoted to special lines of research. Any part of the entire plan, may, however, be completed in itself, and will have a proportionate value to that of the whole. The Institution commenced about fifteen years ago to collect materials on several of the points of this general plan, under the direction of Professors John and Joseph Le Conte, then of the Uni-

versity of South Carolina, now of the University of California. The occurrence of the war, however, interrupted the work, which has not since been resumed until the present year, when an offer was made by Professor F. W. Clarke, of Boston, of a series of tables on *specific gravities, boiling-points, and melting-points* of bodies, compiled from the best authorities. This offer was accepted, and the work has been printed. It embraces all the reliable material in the English, French, German, and Italian languages on the foregoing subjects, with the exception of the specific gravity of solutions, for which reference is made to Storer's Dictionary of Solubilities, a work which will form part of the same general plan and ought to have been published by the Institution, but unfortunately at the time it was offered for this purpose our funds were not in a condition to defray the expense of printing. It has since been published as a private enterprise, and is highly prized by the working chemist.

Professor Clarke is still engaged on the same general subject, and proposes to extend his compilation of tables to include those of specific heat, conductivity of heat, thermal expansibility, and thermo-chemical equations for solids and liquids. This beginning we trust will induce other members of the corps of the Smithsonian collaborators to undertake other parts of the general plan of the constants of nature and art, to be published, from time to time, as they may be prepared. The work being stereotyped, the several parts can be finally combined and arranged as portions of a whole, whatever may be the order of their publication.

Among the "miscellaneous" publications during the year was the first lecture of the course founded by Dr. J. M. Toner, of Washington, by Dr. J. J. Woodward, assistant surgeon, United States Army, "*On the structure of cancerous tumors*, and the mode in which adjacent parts are invaded." In the report for 1872 an account was given of this fund established by Dr. Toner, the interest to be applied for at least two lectures or essays annually, relative to some branch of medical science, and containing some new truth fully established by experiment or observation. As these lectures are intended to increase and diffuse knowledge, they have been accepted for publication in the "Smithsonian Miscellaneous Collections."

It was stated in the last report that Congress had adjourned without ordering extra copies of the report for 1871. At the beginning of the next session, however, a resolution was adopted directing the printing, as usual, of 12,500 copies. An equal number of the report for 1872 was also ordered at the same session; 2,500 for the use of the Senate, 5,000 for the House of Representatives, and 5,000 for the Institution. This volume contains, besides the report of the secretary on the operations of the Institution for the year 1872, the report of the executive committee and journal of proceedings of the Board of Regents, the usual

appendix of scientific papers, communications, translations, &c., of special interest to the meteorological observers, teachers, and scientific correspondents of the Institution.

Among these articles is a lecture by Prof. A. P. Peabody, on the scientific education of mechanics and artisans; aboriginal trade and North American stone implements, by Chas. Rau; optical mineralogy, by Brezina; the troglodytes of the Vézère, by Paul de Broca; organic bases, by Bauer; boundary of geology and history, by Suess; phenomena observed in telegraphic lines, by Donati; nitrogen and its compounds, by Kletzinski; biographical notice of Lartet, by Fischer; eulogy on Ampére, by Arago; lecture on the meteorology of Russia, by Dr. Woeikof, and a large number of original communications relative to antiquities in various parts of the United States, &c. In this volume may also be found a full account of the Bache bequest, the Tyndall trust-fund for the advance of science, the Corcoran art-gallery, the Toner foundation, and the Hamilton bequest.

EXCHANGES.

The system of international exchanges, which has now been in operation for upward of twenty years, has been prosecuted during the last year with increased efficiency. It now includes 2,145 foreign institutions to which packages of books or specimens are sent and from which others are received. In the case of the system of exchanges, as in all the other operations of the Smithsonian establishment, the tendency is to an enlargement beyond the means at our command. Although, through the liberality of the several steamship companies, the packages are transmitted across the Atlantic free of cost, yet the expense of sending them to New York and from the sea-board to the centers of distribution in Europe, together with the payment of the several agents, has become so great that a much further extension of the system cannot be made without aid from other sources.

The system is, however, of so much importance, not only in rendering known what is done in the United States in the way of advancing literature and science to the world abroad, but also in diffusing a knowledge extensively through this country of the progress of science in the various parts of the Old World, that any check in its natural increase would be greatly to be deplored. It has, therefore, been suggested that an appeal be made to the various parties most interested in the continuance and enlargement of this system for a small annual contribution toward its future support and still more efficient management. Indeed, the benefit which the Institution is conferring, through this system, upon the parties most interested, appears in many cases to have ceased to be properly appreciated. They receive the advantages which flow from it as a matter of course, as they do those of the free air, and not as a gratuity

from the Smithson fund, the importance of which can only be properly appreciated by a deprivation of it for a short time. We infer this from the fact of the character of the complaints we frequently receive on account of accidental delay in packages reaching their destination, although in some instances the delay may have been occasioned by a want of proper directions on the part of the senders of the packages.

The centers of reception and distribution of European exchanges still continue the same as given in previous reports, viz: London, Paris, Leipsic, Amsterdam, St. Petersburg, Milan, with the addition of one at Brussels. The agency at London has for many years been in charge of Mr. William Wesley, whose fidelity and unremitted attention to the trust entitle him to an appreciative acknowledgment of the Board of Regents, and the same may be said of Dr. Felix Flügel, of Leipsic, and Mr. G. Bossange, of Paris. The center at St. Petersburg is under the charge of L. Watkins & Co., booksellers, and that at Amsterdam under Mr. Fred. Müller, who have efficiently contributed to the success of the enterprise in these countries. The center in Italy is under the charge of U. Hœpli, as agent for the Royal Institute of Milan.

The expense of transportation is very much increased by sending single packages separately, and therefore, whenever possible, without undue delay, economy is consulted by transmitting the exchanges at regular periods in larger numbers. Arrangements have been made so that invoices of packages are forwarded from this country at least once a month, except in the months of August, September, and October.

The following table exhibits the number of establishments in each country with which the Smithsonian is at present in correspondence:

Sweden	25	Turkey	11
Norway	23	Africa	18
Denmark	29	Asia	36
Russia	157	Australia	26
Holland	65	New Zealand	11
Germany	587	Polynesia	1
Switzerland	68	South America	33
Belgium	127	West Indies	11
France	257	Mexico	8
Italy	167	Central America	1
Portugal	21	British America	27
Spain	12	General	5
Great Britain and Ireland	412		
Greece	7	Total	2,145

As in previous years, the Institution has received important aid from various steamer and railroad lines in the way of free freights, without which the expense of carrying on the system would be far beyond the

means at command. Acknowledgment is again due for the liberality of the following companies:

Pacific Mail Steamship Company,
Panama Railroad Company,
Pacific Steam Navigation Comp'ny,
New York and Mexico Steamship Company,
New York and Brazil Steamship Company,
North German Lloyds Steamship Company,
Hamburg American Packet Company,
French Transatlantic Company,
North Baltic Lloyds Steamship Company,
Inman Steamship Company,
Cunard Steamship Company,
Anchor Steamship Company.

We present the foregoing list with much pleasure, not only as an acknowledgment of the liberality of the companies mentioned, but also as a very gratifying illustration of the high appreciation of the operations of the Institution.

LIBRARY.

The union of the library of the Institution with that of Congress still continues to be productive of important results. The Smithson fund is relieved by this arrangement from the maintenance of a separate library, while at the same time the Institution has not only the free use of its own books, but also those of the library of Congress. On the other hand, the collection of books owned by Congress would not be worthy the name of a national library were it not for the Smithsonian deposit. The books which it receives from this source are eminently those which exhibit the progress of the world in civilization, and are emphatically those essential to the contemporaneous advance of our country in the higher science of the day. The collection of books now in the library of Congress is over a quarter of a million, and, with the present rate of increase, in less than twenty years will be double that number.

To accommodate this immense collection, Congress has in contemplation the construction of a new building, and has authorized a commission to select plans and to supervise the location and erection of an edifice.

Statement of the books, maps, and charts received by exchange in 1873.

Volumes:		
Quarto, or larger	256	
Octavo, or less	633	
		889
Parts of volumes:		
Quarto, or larger	1,467	
Octavo, or less	1,407	
		2,874

Pamphlets:		
Quarto, or larger	326	
Octavo, or less	1,154	
		1,480
Maps and charts		454
Total receipts		5,697

Some of the most important donations received in 1873 are as follows:

From the Emperor of Germany: The fresco paintings of W. von Kaulbach in the interior stair-case of the Royal Museum at Berlin; 12 parts; imp. folio; oblong; 1853–1871. Schasler, (Dr. M.,) Die Wandgemälde Wilhelm v. Kaulbach im neuen museum zu Berlin; 1 vol., 4to. Schneider, Der Königliche Kronen-Orden; 1871, 4to. Schneider, Das Buch vom Schwarzen Adler-Orden; 1870, 4to. Schneider, Das Buch vom Eisernen Kreuze; 1872, 4to. Schneider, Das Verdienst Kreuz; 1872, 4to. Schneider, Die Kriegsdenkmünze für den Feldzug; 1870, 1871, 1872, 4to. Haack, Skizzen aus dem Feldzuge gegen Frankreich; 1870, 1871, 4to. Schneider, Der Rothe Adler-Orden; 1868, 4to. Hans Burghmaiers Turnier-Buch. Dürer-Album, Herausgegeben von W. v. Kaulbach and A. Kreling; folio.

From the Royal Academy of Sciences, Lisbon: 45 vols. and 12 parts; continuation of memoirs and other publications of the academy.

From the Catholic University of Louvain: "Annales," 10 volumes, 4to.; "Annuaire," 3 volumes and 17 theses.

From the government of Bengal: Descriptive ethnology of Bengal, illustrated by lithograph-portraits copied from photographs. Calcutta, 1872, 4to.

From the War Department, Vienna: 384 charts.

From Prof. Edward Morren, Liège: Bulletin de la Fédération des Sociétés d'Horticulture, 1860–1871, 13 vols.; Journal d'Agriculture pratique, vols. I–X; Bulletin de Congrès International de Botanique et d'Horticulture, 1865; La Belgique Horticole, 1871, 1872, &c.

From His Highness, Ismael I, Khedive of Egypt: Album du Musée du Boulaq, comprenant quarante planches photographiées par MM. Délié et Béchard avec un texte explicatif rédigé par Auguste Mariette Bey. Le Caire, 1871; folio.

From the National University, Athens, Greece: Catalogue of Ancient Coins; vol. 1, 4to. (Greek.)

From the University of Halle: 77 pamphlets; inaugural dissertations.

From the University of Greifswald: 70 inaugural dissertations.

From the University of Erlangen: 27 inaugural dissertations.

From Prof. K. Koch, Berlin: 50 inaugural dissertations.

From the Italian government, Rome: 41 volumes, 62 pamphlets, government publications.

From the government of Belgium: 16 volumes and 3 pamphlets, government publications.

From the Société de Géographie, Paris: Voyage d'Exploration in Indo-Chine, 1866, 1867, 1868; vols. 1, 2; atlas 1, 2, 1873; folio, and "Bulletin" for 1873.

From Mr. William Blackmore, London: Portfolio of photographs of some of the principal objects in the British Museum.

From Mr. Charles Harrison, London: Chaldean account of the deluge, from terra-cotta tablets found at Nineveh and now in the British Museum.

Among the donations of special interest during the past year is the photographic album of the museum at Boulaq, Egypt, containing forty folio plates with an explanatory text by Auguste Mariette Bey, printed at Cairo in 1871, and presented to the Institution by the Khedive of Egypt, through the application of Gen. Stone. This museum is situated on the borders of the Nile, near Cairo, and consists of a collection of all the antiquities that have been discovered of late years in Egypt.

After the immense number of antiquities which have been taken from that country to enrich all the principal museums of the civilized world, it is astonishing to observe how much remains, and how much by the enlightened munificence of the present ruler of Egypt has been preserved.

Ten of the plates of this album exhibit the statues of the Egyptian gods, nearly four hundred in number. The next division, consisting of seven plates, illustrates the funeral monuments. The next division is that of the civil monuments; these relate to their every-day life, their manners, customs, and arts. The next illustrates the historical remains. The last division is that of the Greek and Roman monuments.

Another work of great beauty and interest is that published by Mrs. Caroline E. G. Peale, the widow of Franklin Peale, of Philadelphia, as a memorial of her lamented husband. It consists of a series of beautiful photograph illustrations of specimens of the stone age of the human race, collected and arranged by Mr. Peale himself, with a catalogue and introduction, and a reprint of the various communications made by him to the American Philosophical Society.

This work is a valuable contribution to the ethnology of the United States. The photographs are among the best specimens of the art which have been produced in this country, and exhibit the specimens with such minuteness and fidelity as to serve to the student in archæology almost as a complete substitute for the specimens themselves. This work is truly a refined and intellectual tribute by an affectionate wife to the memory of her deceased husband—a tribute far more appropriate, and far more interesting to the public, than an unattesting monument of marble or of bronze. As human culture advances, the material mementos which only address the eye are replaced by those which are almost purely of an intellectual character.

METEOROLOGY.

In 1850 the Smithsonian Institution published an extended series of investigations in regard to the *winds* of North America, by Professor J. H. Coffin, of Lafayette College, Easton, Pennsylvania. In the production of this work Professor Coffin was assisted by the Institution in furnishing materials from its collections, and funds to defray the expense of the arithmetical calculations from the income of the Smithson bequest, the labors of the professor himself being gratuitous. Since the publication of this work, which has been largely made use of by the British board of trade in constructing its wind charts of the northern oceans, and by different authors in compiling and elaborating special treatises on meteorology, the Institution has continued to collect new materials in regard to the winds of the earth, and instead of elaborating from these a supplement to the previous treatise on the winds of the northern hemisphere, it was concluded to adopt the plan proposed by Professor Coffin of making a discussion of the winds of both hemispheres. The materials for this discussion are: First, all the observations reported to the Smithsonian Institution from 1856 to 1870; second, all those made at the United States military posts; third, all those at sea collected at the United States Naval Observatory by Capt. Maury; fourth, all those taken at sea in the Arctic and Antarctic regions; fifth, those at several hundred stations in other parts of the globe.

The greatest labor of the work was principally finished by Professor Coffin, when science and humanity were called to mourn the death of this most highly esteemed collaborator of the Institution. The continuation, however, of the tables was undertaken by the son of our lamented friend, Prof. S. J. Coffin, who has completed this work with that conscientious sentiment of filial reverence which well becomes the appreciative successor of so worthy a father. Very little, however, was finished by the elder Professor Coffin in the way of expressing, in general propositions, the results contained in the vast amount of numerical tables which he had elaborated. To supply this deficiency, fortunately, the Institution was enabled to avail itself of the assistance of Dr. Woeikof, member of the Geographical Society of Russia and late secretary of its meteorological commission, who, visiting this country for the study of its climatology, cheerfully undertook the required work. This gentleman is now engaged in adding the result of some new materials to the tables and in preparing the deductions from them for publication. The work, when finished, will do honor to the industry and scientific reputation of Professor Coffin and to the policy of the Smithsonian Institution.

The work of the reduction of *temperatures* has been prosecuted during the past year as rapidly as our means will permit. The labor, however, is very great, and consequently the work must be slow, unless a larger force be put upon it. The observations are not confined to those which have been made immediately under the direction of the Smithsonian Institution, but also include all those relative to North America which

have ever been published in this country or in Europe. But as these are made not only at different hours of the day, but also at different numbers of hours, to reduce these all to a fixed number of hours, and to deduce from them thus reduced the mean temperatures required, involves a far greater amount of labor than if the observations had been made in accordance with one system. It was to facilitate this reduction that the preliminary tables mentioned in the last report were constructed.

Complete tables have been prepared of temperatures for the following: Iceland, Greenland, British North America, Alabama, Alaska, Arizona, Arkansas, California, Colorado, Dakota, Delaware, Idaho, Indian Territory, Illinois, Montana, Nebraska, Nevada, New Hampshire, New Mexico, New York, Maine, Oregon, Utah, West Virginia, Washington Territory, Wyoming.

In addition to this work, tables showing the latitude, longitude, and mean annual temperature of all the stations in the United States were prepared for the Census Office.

It has been from the first a part of the policy of this Institution to devote its energies to no field of research which can be as well cultivated by other means; and the United States Government having established a system of meteorological observations, and having made liberal appropriation for its support, it has been thought, as was stated in the last report, for the best interest of the science to transfer the system of meteorological observations which has been so long continued by the Institution to that of the War Department, under the Chief Signal-Officer, General Myer.

The propriety of this transfer will be evident from the fact that the Institution has not the means of paying for printing blanks, postage, and the calculation and monthly publication of the results, especially since the assistance which has heretofore been rendered in this way, by the Department of Agriculture, is now discontinued; furthermore, General Myer can combine these observations with those made with standard instruments now under his charge, and out of the whole form a more extended and harmonious system than any at present in existence.

This transfer, which has just been made, we trust will meet the approbation of the observers generally, and we hope they will continue their voluntary co-operation, not with the expectation of being fully repaid for their unremitted labor, in many cases for a long series of years, but from the gratification which must result from the consciousness of having contributed to increase the sum of human knowledge. We trust also that the observers will continue to cherish an interest in the welfare and progress of the Smithsonian Institution, while, on our part, we shall in all cases, and at all times, be pleased to continue to answer any communication which may be addressed to us by them on scientific subjects.

We shall retain all the records of observations which have been accumulating at the Institution during the last twenty-five years, and continue the work of their reduction and discussion up to the end of the year 1873.

TELEGRAPHIC ANNOUNCEMENTS OF ASTRONOMICAL DISCOVERIES.

During the past year a very important arrangement has been concluded between the Smithsonian Institution and the Atlantic cable companies, by which is guaranteed the free transmission by telegraph between Europe and America of accounts of astronomical discoveries, which, for the purpose of co-operative observation, require immediate announcement.

Among such discoveries are those of planets and comets, or of bodies which are generally so faint as not to be seen except through the telescope; and which being in motion, their place in the heavens must be made known to the distant observer before they so far change their position as not to be readily found. For this purpose the ordinary mail-conveyance, requiring at least ten days, is too slow, since in that time the body will have so far changed its position as not to be found except with great difficulty; and this change will become the greater if the body is a very faint one, for in that case it could only be discovered on a night free from moonlight, which of necessity, in ten or twelve days, must be followed by nights on which the sky is illuminated by the moon, and all attempts to discover the object would have to be postponed until the recurrence of a dark night. Indeed, even then the search often proves in vain; and it is not, in some cases, until after a set of approximate elements are calculated and transmitted, that the astronomers on the two sides of the Atlantic are able fully to co-operate with each other.

These difficulties were discussed by some of the principal astronomers of Europe, and an application was made to the Smithsonian Institution, through Dr. C. H. F. Peters, of Hamilton College, New York, to remove them, by transmitting intelligence immediately through the Atlantic telegraph cable. For this purpose the Institution applied to the New York, Newfoundland and London Telegraph and to the Western Union Telegraph Companies to be allowed free transmission of this kind of intelligence, and it has received, through Cyrus W. Field, esq., and William Orton, esq., with that liberality which has always attended applications of a similar character by the Institution, the free use of all the lines of these companies for the object in question.

Similar privileges have been granted for transmitting the intelligence between the principal centers of astronomical research in Europe and the eastern ends of the Atlantic cables.

Although the discovery of planets and comets will probably be the principal subject of the cable-telegrams, yet it is not intended to restrict the transmission of intelligence solely to that class of observation. Any remarkable solar phenomenon presenting itself suddenly in Europe, observations of which may be practicable in America several hours after the sun has set to the European observer; the sudden outburst of some variable star, similar to that which appeared in *Corona borealis* in 1866; unexpected showers of shooting-stars, &c., would be proper subjects for transmission by cable.

The announcement of this arrangement has called forth the approbation of the astronomers of the world; and in regard to it we may quote the following passage from the fifty-fourth annual report of the Royal Astronomical Society of England:

"The great value of this concession on the part of the Atlantic telegraph and other companies cannot be too highly prized, and our science must certainly be the gainer by this disinterested act of liberality. Already planets discovered in America have been observed in Europe on the evening following the receipt of the telegram, or within two or three days of their discovery."

To carry out the proposition, the following arrangements have been adopted:

Center of communication in the United States:

1. The Smithsonian Institution, Joseph Henry, director.

Centers of communication in Europe:

1. Greenwich Observatory, Sir George B. Airy, astronomer-royal.
2. Paris Observatory, M. Leverrier, director.
3. Berlin Observatory, Prof. W. Foerster, director.
4. Vienna Observatory, Academy of Sciences, Prof. von Littrow, director.
5. Pulkova Observatory, M. Struvé, director.

Telegrams received at the Smithsonian Institution from observers in the United States will be forwarded immediately by Atlantic cable to Greenwich, Paris, Berlin, Vienna, and Pulkova, and thence by telegraph to other observatories in Europe.

Directions.—Discoveries made in Europe of new comets, planets, &c., will be announced without delay from Greenwich, Paris, Berlin, Vienna, or Pulkova by Atlantic cable to the Smithsonian Institution, and thence by telegraph to American observatories and the Associated Press.

The telegraphic dispatch announcing a discovery should be as brief as possible; and, after conference with astronomers, the following form has been agreed upon:

After the single word "planet" (or "comet") is given,

(1st) its right ascension in time, hours and minutes only; next, separated by the word

(2d) *north* or *south*, is given its

(3d) declination to the nearest minute.

In the case of a *planet*, in addition to the foregoing follows finally the magnitude expressed by the nearest ordinal number. In the case of a *comet* follows the word *bright* or *faint*, and it is well to add the direction of motion, requiring at the utmost two words combined, of S. W. N. E.; and also, if rapid, the quantity of its daily motion, the latter to the nearest whole number in degrees. For example, the following dispatch, "Planet twenty-three thirty-five north twenty-one forty-six eleventh," would be interpreted: A new planet is discovered in $23^h\ 35^m$ of right ascension and $+21^\circ\ 46'$ of declination; eleventh magnitude.

Or a dispatch like the following: "Comet twenty-two forty-three north

sixty-five thirty-one bright southeast three," would announce the discovery of a bright comet in right ascension $22^h\ 43^m$; declination $+ 65^\circ\ 31'$; the declination decreasing, right ascension increasing, daily motion about three degrees.

The preceding examples contain the greatest number of words required for any one dispatch, if composed according to the rule adopted. Usually they will not exceed ten. Sometimes, however, the dispatch thus composed would become equivocal, and it has therefore been established as an additional rule that the number expressing the minutes of right ascension or declination shall always be expressed in words, even when zero occurs. Therefore, $23^h\ 0^m$ should be written "twenty-three nought," while "twenty three" will be understood to mean $20^h\ 3^m$. In a similar way 0^h of right ascension or 0° of declination are to be distinctly expressed by the word "*nought.*"

The right ascension and declination in the dispatch will be understood to give the position (by proper motion approximately reduced) for the *midnight following* the date of the dispatch: Washington time for American discoveries, Greenwich time for European.

Since, in conformity with the preceding article, only an approximate estimate of a later position, and not that of the first observation itself, is given, the dispatch is not to be considered as a document for deciding the question of priority of discovery.

We trust the time is not distant when, with the completion of a telegraphic cable between Japan and the United States, this system will be extended to the eastern part of Asia, and the astronomers who are now in process of education in the United States, both from China and Japan, will be able to participate in the facilities thus offered for co-operation in the advance of astronomy. In connection with the publication of this circular, the National Academy of Sciences, at its meeting on the 15th of April, adopted a resolution recommending that amateur astronomers devote a portion of their time to sweeping the sky for the discovery of comets.

The following is a list of the announcements during 1873:

Discovery.	Date of telegram.	From whom.	Place.	Right ascension.	Declination.		Motion.	Magnitude.
	1873.			h. m.		° ′		
Planet	Feb. 18	Peters	Clinton, N. Y.	10 0	N.	13 40	N.	Eleventh.
Planet	May 26	Peters	Clinton, N. Y.	16 14	S.	21 18	W.	Eleventh.
Comet	July 5	Tempel	Vienna	0 7	S.	4 34		
Planet	July 14	Watson	Ann Arbor, Mich.	17 16	S.	21 43	N.	Eleventh.
Comet	July 27	Borelli	Marseilles	1 14	S.	7 32	S. E.	
Planet	Aug. 17	Watson	Ann Arbor, Mich.	23 2	S.	2 40	S.	Eleventh.
Comet	Aug. 21	Borelli	Marseilles	7 27	N.	38 45	S.	
Comet	Aug. 22		Vienna	7 29	N.	36 55	S.	
Comet	Aug. 24	Henry	Paris	7 27	N.	59 30	E.	
Planet	Sept. 27	Luther	Düsseldorff	0 7	N.	7 53	S.	Tenth.
Comet	Nov. 11	Coggia	Marseilles	16 23	N.	27 26	S.W.	
Comet	Nov. 12		Vienna	16 4	N.	22 6	S.W.	

NATIONAL MUSEUM.

The appropriation by Congress of $15,000 for the support and exhibition of the museum was continued last year. This appropriation, however, was scarcely sufficient to defray the expenses; but as Congress within the last two years had also granted $12,000 for heating-apparatus, and $25,000 for the fitting up with cases of additional rooms for the accommodation of the collections, a larger sum than $15,000 was not asked for the care of the specimens. During the last year a steam-heating apparatus has been introduced under the direction of Lewis H. Leeds, of New York, heating and ventilating engineer. The contract for the work was awarded to Messrs. Blake & Shotwell, of New York, who have faithfully carried out the plan adopted.

We regret to say, however, that the boilers, placed as they are in the middle of the length of the building, are scarcely sufficient in size to heat the extreme ends, and that during the coldest weather additional apparatus will be required. In the appendix is given a report of the engineer, with a plan of the several stories of the building.

The contract for making cases for the mineralogical department was given to John H. Bird, who has executed the work to the entire satisfaction of the Institution. The contract for constructing the cases for the large room of the upper story was awarded to John W. McKnight. These cases are of pine, veneered with walnut and bird's-eye maple, with large panes of English plate-glass, and are covered at the top and bottom with zinc to render them dust-proof. They are much more elaborately finished than museum-cases usually are, and this too at a much less expense than that of the various cases in other public buildings of this city. The plans and specifications of these cases, with a model case, were prepared by Prof. H. A. Ward, of Rochester, N. Y., with some modifications by Mr. A. Cluss, who has for several years been the architect of the Smithsonian building. The construction of the cases by Mr. McKnight was completed to the entire satisfaction of Mr. Cluss, the architect, not, however, without a complaint on the part of the contractor that his estimate of the cost of the work was far from being at a remunerative rate. The appropriation was sufficient to complete the cases, but not to furnish them with shelves. For this, an additional appropriation will be required. It is proposed to devote the large room, which is 200 feet long and 50 wide by 25 in height, entirely to ethnology, this being a branch of science attracting perhaps at the present time more attention than almost any other, and of which the illustrations at present in the general collection of the National Museum are nearly sufficient to fill the entire space and are rapidly increasing in number.

The appropriation of $15,000 for the care of the museum has provided for the employment of an additional assistant to take charge of the mineralogical collections. The person appointed to this position is Dr. F. M. Endlich, of Reading, Pa., who has lately completed his scientific

studies in Germany, at the Mining Academy of Freiberg, having paid special attention to the blow-pipe analysis of minerals. He has rendered efficient service not only in the arrangement of all the minerals of the museum, but in making up sets from the large number of duplicates for distribution to colleges and academies. Previous to the employment of Dr. Endlich, the duplicate minerals and geological specimens were sent to the School of Mines of Columbia College, New York, where they were examined and made up into sets for distribution, the minerals by Professor Egleston, and the rocks by Professor Newberry. In this line the Institution has done good service to the cause of education, and has the capacity of doing much more, provided the small amount of funds required for the purpose be granted by Government.

The appropriation of Congress has also enabled us to add a permanent taxidermist to the establishment, Joseph Palmer, from England, who has not only much improved the condition of the mounted specimens previously in the Institution, but, under the direction of Professor Baird, has added a large number of new specimens, especially a series of several hundred plaster casts taken from fresh fish and painted to represent the colored appearance of nature.

Few persons have any idea of the amount of manual labor necessary to properly sustain a museum in a condition fit for public exhibition. Heretofore, with the limited amount of money which could be expended from the Smithsonian fund, in addition to the $4,000 allowed by Congress, it was impossible to keep the specimens in the best condition either for critical study or for popular exhibition. The museum, therefore, although it has been an object of great interest to the public generally, has not been what we trust it will be in the future.

The following report of Professor Baird, of the additions to the museum, and the various operations connected with it during the year 1873, presents satisfactory evidence of prosperity.

Condition, progress, and operation of the National Museum during the year 1873.—"The record of the National Museum for 1873 is highly satisfactory, showing valuable additions from many parts of the world, and considerable progress in the way of reducing its contents to order, and making them serviceable to the cause of science. In no previous year has the number of distinct donations been so great, while the bulk of the parcels received has been almost inconveniently large. The total number of entries is 441, from 241 donors, and embraces 680 packages of different kinds, the similar figures for 1872 being 315, 203, and 544, respectively.

A list in the appendix will show in detail what has been actually received, including the names of contributors and the nature of their donations; the increase being in large part from the collections of different Government exploring expeditions, which by law of Congress are transferred to the Smithsonian Institution for safe-keeping, and also

from the contributions of special correspondents of the Institution, and by exchange. Nothing has been added in the way of direct purchases. While most large museums, such as the British Museum and those of Paris, Berlin, and Cambridge, Mass., &c., depend principally upon purchases for increasing their collections, the National Museum, without funds at its disposal for such purpose, has not yet felt the need of them; the collections received from the sources mentioned, free of cost other than that of mere transportation, being quite as great as the means of preparation and preservation will allow.

In addition to the number of donations, the entries in the record-books of the museum during the year 1873 will indicate approximately the extent and nature of the increase; the total number of entries during the year amounting to 10,604, or 33 per cent. more than those of 1872; the largest number, that of birds, amounting to 3,232 specimens; of fishes, 2,756; of ethnological specimens, 1,475; and of minerals, 941. This, however, does not represent accurately the number of separate specimens, as many objects of the same kind and from the same locality are often included under a single entry. Many additions during the year, especially of shells, minerals, and fishes, are yet unrecorded.

The total number of entries to the end of the year amounts to 187,453, filling thirty large folio ledgers. As might be expected, the principal sources of supply have been from American localities, the United States especially, although some objects of interest have been received from other parts of the world. The special object has been to bring together as complete an exhibition of the natural history and ethnology of America as the available means would permit. Should Congress at any future time decide to increase the scale of operations so as to enable the establishment to vie with such museums as those of London, Paris, Berlin, Vienna, &c., the framework of the present organization can be readily expanded so as to cover a much wider field. At present the available space for exhibiting specimens is occupied to its utmost extent, and but a portion of the collections actually within the walls of the Institution can be exhibited to the public. The remainder, however, are in such a condition as to be available for the study of specialists whenever they may find it necessary to examine them.

For the better understanding of the character of the collections received in 1873, a general sketch is given with reference to the regions whence they were derived, to be followed by an enumeration, in systematic sequence, of those of the most importance.

Of comparatively slight extent, yet perhaps of greater interest from their historic associations than any others, are the collections made during the eventful voyage of the Polaris, under Captain Hall, to the northern regions. This expedition, fitted out by the Navy Depart-

ment in pursuance of an act of Congress, left the United States in the summer of 1871, and succeeded in reaching the latitude of 82° 16′, the most northerly point ever attained by civilized man. Little was done in the way of collections until after the expedition went into winter-quarters in October, 1871; and most of the specimens gathered were secured during that winter and the following spring and summer. The death of Captain Hall interfered, of course, materially with the scientific work, but did not interrupt it, and at the time of the damage to the vessel by the ice, in October, 1872, very extensive collections had been made under the direction of Dr. Bessels, the chief of the scientific corps. These embraced specimens of the minerals, rocks, and fossils of Polaris Bay and other localities, large numbers of skins and skeletons of the musk-ox, (a great desideratum in public museums,) and other species of mammals, such as lemmings, seals, &c.; some birds and their eggs; many specimens of marine invertebrates, and a complete collection of the insects and plants met with by the party. Most of these collections were left on board the Polaris when the party remaining with the vessel went into quarters on shore during the winter of 1872–'73; and when the vessel was found to be unseaworthy, and it became necessary to build boats to move southward for the purpose of trying to meet the English whalers, it was found impossible to bring away more than a small number of the objects that had been gathered. Dr. Bessels, however, in the limited amount of space allotted to him, succeeded in packing a representative series of the fossils and rocks, and some specimens of insects, as also a few objects preserved in alcohol, all of which at present occupy a special case in the mineral-room at the west end of the Smithsonian building.

The absence of fishes in the collections of the Polaris party is very remarkable, no specimens of this class of vertebrates having been seen by the expedition in the northern portion of their journey, with the exception of a few small fishes in a fresh-water stream, which could not be caught, but were supposed to be young salmon. Cetaceans, too, were equally absent, the marine mammals being represented only by one or two species of seal.

Proceeding southward, the next region from which interesting material has been received during the year is that of the Pribylov or fur-seal islands of Behring Sea. Here the collections begun in 1872, on the island of Saint Paul, by Mr. Henry W. Elliott, assistant United States Treasury agent, were continued by him on the adjacent island of Saint George, and embraced a complete representation of the birds, especially the aquatic species and their eggs, the skeletons and skulls of the seals and some marine invertebrates. These are accompanied by very interesting sketches of the animal life of the island, especially of the seals and walruses, adding much to our knowledge of the habits of this interesting group of mammals.

The westernmost portion of the chain of the Aleutian Islands was thoroughly explored during the year by Mr. William H. Dall, while engaged in making a survey of the islands in behalf of the United States Coast Survey, his leisure time having been employed in securing a wonderfully complete series of specimens for the National Museum. These covered all departments of natural history, such as various mammals, birds and their eggs, insects and plants, and more especially marine invertebrates, of which it is believed that many new species have been obtained. A very prominent feature, however, in Mr. Dall's collections, consists in the extensive series of pre-historic objects obtained by the exploration of certain burial caves in Unalaska, which throw much light upon the past relationships of the Aleutians. Including the ethnological collections made by Mr. Dall during previous years, it is believed that no better illustration of the anthropology of that part of Alaska could be brought together than is now within the walls of the Institution.

A collection of carvings made by the Haidah Indians, of Queen Charlotte's Island, a tribe remarkable for their skill in this branch of art and for the variety and grotesqueness of their designs, has been received from Mr. J. G. Swan, whose contributions also embrace numerous ethnological and other specimens from Washington Territory, and is accompanied by a memoir, previously noticed in this report.

From Oregon we have a very remarkable collection of pre-historic remains, many of them of exquisite beauty of workmanship, consisting of arrow-points and pestles, bone-carvings, &c., presented by Mr. Paul R. Schumacher, of the United States Coast Survey.

Another valued addition from this part of the country consists of a number of specimens of the showt'l, both in skins and entire in alcohol, furnished by Mr. S. C. Wingard, the United States district attorney at Olympia. This mammal, the *Aplodontia leporina*, is like a muskrat, but with a very short tail, and although abundant in a very limited locality, is still little known to naturalists; while its peculiarities of form render it of great interest as an object of study. After many years of special effort directed toward securing a supply of these animals for the purpose of meeting some urgent calls, the object was finally accomplished by the aid of Mr. Wingard.

The coast of California has been well represented by the collections of Captain C. M. Scammon, of the United States Revenue Marine. This gentleman, an active and efficient officer of the service, has, in the interest of science, made use of the opportunities furnished by the necessary cruises along the coast, devoting himself especially to a careful scientific and practical study of the marine mammals, including the whales, porpoises, seals, sea-otters, &c. With commendable enterprise, he has commenced the publication, in California, of a large work on this subject, which, with its well-executed illustrations, promises to be a complete

treatise upon the whale-fishery and other similar interests on the Pacific Ocean, and one that will doubtless be a standard of reference in the future.

The collections made by Captain Scammon for his studies in this department have been transmitted by him from time to time to the National Museum, where they constitute one of its most unique and important features. Too much cannot be said in praise of gentlemen like Captain Scammon, who, in addition to the routine of their official work, labor for the advancement of science, and especially where such labor can be turned to practical account as in the present instance.

The United States steamer Tuscarora, under Commander G. E. Belknap, has been engaged during the summer in making soundings in the Pacific, from San Francisco toward the Aleutian Islands, with the object of determining the proper line for a cable between the United States and Japan; and numerous specimens of sea-bottom, with its microscopic *fauna*, were secured, and have been recently transmitted by Com. Ammen, of the Bureau of Navigation, in behalf of the Navy Department, with the request that the Smithsonian Institution would have them properly investigated and reported upon.

From the main-land of California collections have been received from Dr. J. G. Cooper, of San Francisco, Mr. W. A. Cooper, of Santa Cruz, and Dr. Hays, of Santa Barbara, consisting of specimens of birds, mammals, &c., of much interest.

By far the most extensive collections received by the National Museum during the year have been the result of Government expeditions in the regions west of the Missouri.

The first of these in geographical order, beginning at the north, is that of the survey of the boundary between the United States and the British territory, prosecuted under the auspices of the State Department, and under the direction of Mr. Archibald Campbell as commissioner. The proper determination of this boundary, in which Great Britain takes part, requires careful astronomical and geodetic work, this being conducted by Major Twining in behalf of the United States Engineer Department. The region traversed is one very little known, and the commissioner, therefore, as was the case during his survey of the western end of this line, took pains to secure the assistance of a competent specialist to make the necessary examination in regard to the natural-history resources of the country. Dr. Elliott Coues, assistant surgeon, United States Army, who has had much experience in similar duties, and who occupies a high rank as a naturalist, was chosen as surgeon to the scientific party, and succeeded, with the assistance given him by the commissioner, in making a very large collection of specimens in many branches of natural-history, and one especially rich in the department of ornithology.

The line surveyed during the year extended for several hundred

miles west of the Lake of the Woods, and will be continued in 1874, it is hoped, under the same auspices, to the summit of the Rocky Mountains or to the junction with the line which, in 1860, had been extended from the Pacific Ocean eastward.

The next Government expedition, in geographical position, was one sent out by the War Department to protect the exploring and construction parties of the Northern Pacific Railway, and placed under the command of Gen. David S. Stanley. This consisted of a very large force of men, some two thousand in all, as being necessary to protect the railroad parties against the threatened attacks of hostile Indians. Recognizing the propriety of utilizing so favorable a service in the interest of science, when it could be done at so trifling an expense, the Secretary of War authorized the appointment of a corps of naturalists for the expedition, and Mr. J. A. Allen was placed in charge of this, with several assistants. The expedition proceeded westward from Fort Rice to the Upper Missouri, and crossed some distance beyond the Yellowstone. The results of this expedition are very interesting, and would have been much more extensive but for the necessity of moving in constant apprehension of hostile attacks.

The geographical and geological exploration of the Territories, under Professor Hayden, furnished the next source of museum supply, the researches of himself and parties having extended over parts of Colorado and New Mexico. These furnished very large collections of fossil remains, of minerals and rocks, and of objects of natural history generally.

The exploration of the region west of the hundredth meridian, under the direction of Lieut. George M. Wheeler, of the United States Engineers, has also furnished a large mass of material, equal in extent and general character to that of Professor Hayden, the two parties together contributing a very large proportion of the general results of the year. Thousands of birds and hundreds of mammals, with tons of fossil and geological specimens, are counted in the aggregate received from these two expeditions.

From the explorations of Maj. J. W. Powell, in the cañons of the Colorado, most extensive collections have also been received; his survey being unique in the great extent and completeness of its ethnological representation. In these and the collections of the previous summer, the National Museum now owes to Major Powell's exertions a most interesting and extensive representation of the habits, manners, and customs of the Ute Indians, including every form of dress and personal adornment, of weapons of war and of the chase, of household and agricultural utensils, specimens of their food in different stages of preparation, and whatever else may throw light upon the habits and characteristics of one of the most primitive people on the American continent. A special feature of this collection is the number and variety of stone implements used for various purposes, properly mounted, and showing

the mode by which the knives and arrow-points are attached for every-day use.

New Mexico, Arizona, and Utah, are represented largely in the collections of Lieutenant Wheeler, and of Major Powell; and a collection of skins and eggs of birds, gathered in Southern Arizona, and presented by Capt. Charles Bendire, of the United States Cavalry, has also proved a very important addition to the treasures of the museum. Captain Bendire, while stationed near Tucson, embraced the opportunity to make complete collections of eggs of the Arizona birds, and among them are many previously unknown to naturalists. With commendable liberality, he has presented a series of these to the National Museum, which, from their beauty of preparation and rarity, constitute a very acceptable donation.

Among the collections received from the West must not be omitted: specimens of the salmon, trout, and other fresh-water fishes of the Upper Sacramento, gathered by Mr. Livingston Stone, deputy United States Commissioner of Fish and Fisheries. This gentleman has been engaged for two years on the McCloud River, near Mount Shasta, in obtaining eggs of the Sacramento salmon for supplying the rivers and lakes of the United States with this important food-fish, and he combined with his other duties the securing of material for a complete monograph of the salmonidae of the American continent. He has also furnished some interesting ethnological specimens.

The collections in the regions between the Mississippi River and the Atlantic, although from no one point of very great extent, have furnished a considerable aggregate, and are especially rich in objects of ethnology, to which special attention has been given during the year. The number of donations in this department is very great, and will be found recorded in detail in the accompanying list of contributions, the principal States represented being Michigan, Ohio, Indiana, Maryland, Rhode Island, Maine, &c.

Among the additions in other departments, we may specially mention the collection of fishes by Mr. James W. Milner, also an assistant of the United States Fish Commission, who has had special charge of ascertaining the character of the fish, and reporting upon the fisheries of the great lakes, and of the upper tributaries of the Mississippi. In connection with this inquiry, Mr. Milner secured a very complete collection of food-fishes of the lakes and of the Ohio River, which, in accordance with law, have been sent to the National Museum, and, it is hoped, will form the basis of a work upon the subject.

Having referred to the additions to the collections of the National Museum from the Pacific coast, we have to record also very important contributions from the labors of the United States Commission of Fish and Fisheries.

Of these full series are preserved in the National Museum for investigation, and the great number of duplicates gathered for that special

purpose are in the process of being made up into sets for distribution to colleges and academies throughout the country. No greater aid can be given to the cause of scientific education than to furnish such series as these; and accompanied as they will be by the report of the commission, in which these objects are fully and systematically described, they will be much sought after by institutions such as those referred to.

As in previous years, the facilities of the commission were eagerly embraced by scientific specialists, who spent a greater or less time with the expedition. Among these may be mentioned Mr. G. Brown Goode and Professor Rice, of Wesleyan University, Middletown; Professor J. E. Todd, of Taber College, Iowa; Professor Nelson, of Delaware College, Ohio; Dr. P. P. Carpenter, of Montreal; Mr. S. J. Smith and Mr. Thatcher, of Yale College, and many others on the United States steamer Blue Light, furnished by the Navy Department.

In addition to the collections made at Peak's Island, many interesting objects were secured under the commissioner's direction, by Dr. A. S. Packard, on the United States steamer Bache, which the superintendent of the coast-survey kindly supplied to the commission for a month, for the purpose of deep-sea exploration at points of the New England coast too remote for the services of the Blue Light. Mr. Vinal N. Edwards, an agent of the commission, at Wood's Hole, Massachusetts, also secured great numbers of fishes, several of them previously unknown to our waters.

Other collections of the coast-fishes of great interest were furnished by Messrs. Middleton, Carman & Co., of New York, including a species of perch, *Promicrops guasu*, taken in Saint John's River in Florida, weighing 750 pounds. A series of the Virginia coast-fishes was also received from Mr. Sibley, of Norfolk.

Mr. Samuel Powel of Newport, R. I., furnished some very rare species of fishes from Narragansett Bay. Others from Staten Island have been presented by Mr. Charles Copley.

In the completion of the account of collections received from the eastern coast of North America, we may mention specimens of the salmon family, as salmon, salmon-trout, and white-fish, from the United States salmon-hatching establishment, under the charge of Chas. G. Atkins of Bucksport, Me.; from E. M. Stilwell, fish commissioner of Maine; from Mr. J. B. Blossom, of Brooklyn; from Mr. Rutter of Frederickton, New Brunswick; and of capelin, from Mr. Delaney of Newfoundland. Of even greater interest than any of these, however, were specimens of a gigantic cuttle-fish, presented by Archibald Munn, of Harbor Grace, Newfoundland. For some years past there have been traditions of the occurrence of giant cuttle-fish, or so called "devil-fish," on our eastern coast, although the stories communicated in regard to them have been considered rather fabulous. During the year 1873, however, several well-authenticated cases have occurred, and in one instance an animal of this family attacked a fishing-boat by throwing two of its arms across it, which, however, the

occupants of the boat promptly severed with an ax, and the portions thus secured were brought into port. One of these pieces of an arm measured 18 feet in length, and it was estimated that an equal length remained attached to the body. An entire animal was afterward taken in a net, with arms about 30 feet in length. Another of a similar size was thrown upon the shore, near Harbor Grace in the winter of 1872–'73, the beak and suckers of which were forwarded to the Smithsonian Institution.

The collections from Mexico received during the year have continued to be of much importance, especially such as are covered by the contributions of Professor Sumichrast, who is a resident of the Isthmus of Tehuantepec, and has been for many years a valued correspondent of the Smithsonian Institution. From this gentleman we have received large numbers of birds, mammals, and reptiles, the object of most interest being the skeleton of the Mexican tapir, an animal until recently but very little known.

From Guatemala an interesting addition consists of a specimen of the ocellated turkey, presented by Mr. Sarg, being a species of great rarity, and very much superior in beauty to the wild turkey of North America.

A very noteworthy addition to the collection of the Institution was received from Prof. William M. Gabb, who has been engaged in exploring certain regions of Costa Rica, in the service of that government and of the Costa Rica Railway. This contribution contains many specimens illustrative of the habits and manners of the native tribes of Costa Rica, with a large collection of the birds, mammals, reptiles, fishes, &c., the whole forming a very full representation of the zoology and ethnology of that country.

Additional contributions, in the way of specimens of the natural history of the United States of Colombia, have been received from Gen. Stephen A. Hurlbut, late United States minister to that country, and from his son, Mr. George H. Hurlbut. To these gentlemen the National Museum previously owed the contribution of a skeleton of the tapir of the Andes, a species till then known only by a skull in the Paris Museum. The more recent donations consist of birds in great variety, and other objects.

Several collections have been received from more southern portions of South America, among them an interesting contribution of Peruvian antiquities, presented by Mr. W. W. Evans, and a stuffed specimen of the tapir of the Andes, from President Moreno, of Ecuador.

From the West Indies an important contribution consists in skeletons and alcoholic specimens of the fish of Cuba, presented by Prof. F. Poey, of Havana. Professor Poey is an eminent naturalist, whose writings upon the fishes of the West Indies are standard authority, and he has kindly undertaken to supply to the National Museum a complete series of Cuban fishes, properly named, to correspond with his own publica-

tions. Of these, over one hundred species have already been received, and others are hereafter expected.

The fishes of Bermuda are represented in a collection made by Mr. G. Brown Goode, in behalf of the Wesleyan University at Middletown, by which institution it was presented.

Other notable additions to the collection of fishes consist in specimens of the turbot, the sole, and the brill, of Europe, obtained through Messrs. Middleton and Carman, of New York, for the purpose of showing the relationship of these well-known food-fishes with our own. These specimens have been cast in plaster, and will shortly be placed on exhibition.

Quite a number of single specimens of various kinds have been received in exchange from European museums, although nothing specially noteworthy, with the exception, perhaps, of a collection of minerals from the salt-mines near Cracow, in Austria, presented by the University of Cracow, through Professor Att. Of contributions from other regions outside of North America, by far the most interesting representation is that of New Zealand, as furnished by the Canterbury Museum at Christ Church, in charge of Dr. Julius Haast. This embraces several complete skeletons of the giant fossil birds of New Zealand, species, in comparison with which, the ostrich is but as a chick to a hen, a height of 15 feet, with other dimensions proportionate, being attained by several of the species. There is also in this collection a very good series of New Zealand birds and many specimens of ethnology in the form of implements of stone and bone, and other objects from the shell-heaps of the ancient Maori inhabitants, who were cotemporaries of the giant birds, (the moas,) and the remains of whose feasts contain fractured moa bones in great numbers.

Systematic summary.—Having thus given an account of the more important collections received during the year in their geographical relationships, a brief recapitulation by systematic arrangement may not be uninteresting.

The department of ethnology is one which has received the most varied and extended contributions during the year, due largely to the fact that special effort has been directed by the Smithsonian Institution in the way of circulars to correspondents, and otherwise, to induce the making of such collections, while in preparing instructions to the Government expeditions this subject has been dwelt upon particularly.

Reference has already been made to the prehistoric remains collected by Mr. Dall in Alaska, and by Mr. Schumacher in Oregon, and to those of more modern times furnished by Mr. Swan from Washington Territory and Queen Charlotte's Island, while the objects brought by Major Powell from the Colorado River, are of unusually great extent and value. Every State in the Union, however, has been represented to a greater or less extent in the form of stone-axes, pipes, pottery, &c. The

shell-heaps of Casco Bay were explored by parties connected with the United States Fish Commission, and those of Eastern Maine by Lieutenant Slamm of the Revenue Service. From foreign localities the most interesting contribution is that of the remains from the shell-heaps of the ancient moa-hunters of New Zealand, referred to as contributed by Dr. Haast. The interest of these localities is heightened by the fact that they embrace remains of the gigantic fossil *dinornis*, or moa-bird, proving that this was hunted and eaten by the Maoris.

Of the mammalia, a special prize has been a complete skeleton of the grizzly bear, killed by Lieutenant Carpenter, of Professor Hayden's expedition. Of this animal it is difficult to obtain good skeletons, and the one received was therefore especially acceptable, as it enabled the Institution to meet an urgent request on the part of the British archaeologists. Among sundry fossil bones of bears found in Great Britain and elsewhere in Europe, are remains which cannot be satisfactorily referred to any European animal; and it has been suggested that probably the American grizzly was at one time an inhabitant of Europe, and since then exterminated. The loan of this specimen to a committee of the British Association, charged with the investigation of the subject may enable them to determine this point. For its better illustration, however, the Smithsonian Institution added to the grizzly a specimen of the barren ground bear of the Arctic region, a very rare animal, and of which the only specimens preserved are in the museum at Washington. It is possibly the Arctic species, rather than the grizzly, which will be found to have the closest relation to the European fossil, or cave bear, in this respect exhibiting a parallel to the musk-ox, which once inhabited Central Europe, and after the glacial period was driven back to the northward by the increasing temperature of the continent, and finally entirely exterminated from the Old World. It is now only found living in America and Greenland.

Two very complete skins of the musk-ox, from Arctic America, have been forwarded to the Institution by Mr. William L. Hardesty, of Fort Simpson, and their arrival is expected at an early date. The collections of the remains of cetaceans, such as the skulls of whales and the skins and skeletons of porpoises, &c., from the California coast, as contributed by Captain Scammon, have been already mentioned; as also that of the *Aplodontia-leporina*, or showt'l, which has been received from Mr. S. C. Wingard.

To Professor Sumichrast, of Tehuantepec, the Institution owes the contribution of a skeleton of the tapir of Mexico.

A complete series of the mammals of Costa Rica and their skulls, furnished by Professor Gabb, is of great value.

Among the rarest of mammals is included the hairy tapir of the Andes, from South America, the only representative of the species heretofore being a skull in the Paris Museum.

To the Hon. S. A. Hurlbut, at the time United States minister to

Bogota, and to his son, George H. Hurlbut, the Institution owes the first complete skeleton of this animal ever obtained; and during the year 1873 it received a mounted skin, presented by President Morèno, of Ecuador.

The Museum of Comparative Zoology at Cambridge has furnished, in exchange, casts of several crania of mastodons.

Among the most important contributions in the way of mammals are the specimens received from Mr. P. T. Barnum, consisting of animals which have died in his extensive menageries in different parts of the country, and transmitted to the National Museum from time to time by his agents, in compliance with his instructions. Among these may be mentioned a Malayan tapir, a Bactrian camel, a dromedary, an African panther, the Florida manatee, the Indian rhinoceros, the mandrill and other species, all of them of extreme interest, furnishing both skeletons, and skins fit for mounting.

Of birds the most important collections are those from the Aleutian Islands, received from Messrs. Dall & Elliott, and from the region west of the Missouri, from the different Government expeditions already enumerated. Dr. Haast has also supplied many rarities from New Zealand. A special acquisition is that of the ocellated turkey from Honduras, presented by Mr. Sarg. This is extremely rare in public museums, with a market-value, for a good skin, of about $200.

Other notable contributions are the skin of two species of tern or mackerel gulls, one the *Sterna longipinnis*, from Portland, Me., by Mr. Franklin Benner, and the other *Sterna leucoptera*, from Wisconsin, presented by Dr. T. M. Brewer, both of them the first specimens of their respective species hitherto detected in North America.

A collection of eggs of birds from Arizona, by Captain Bendire, has also been referred to, and is of special value.

Comparatively few reptiles have been received during the year; these consisting mainly of specimens brought in by the Government expeditions. We may, however, mention several valuable species from the Isthmus of Tehuantepec, sent on by Professor Sumichrast, and from Costa Rica by Professor Gabb.

The list of fishes is very extensive, composed mainly of those brought in by the United States Fish Commission. These embrace a very great variety, including specimens of sharks, rays, and many notable fish secured on the coasts of Maine, Massachusetts, Rhode Island, &c., as well as of sea salmon, lake salmon, white-fish, smelts, capelin, and other varieties from the waters of California, the Great Lakes, the Eastern States, and the provinces. Many fishes were brought in also by the Government expeditions, and some have been received from Costa Rica through Professor Gabb, and several interesting species from Europe, through Messrs. Middleton & Carman, of New York.

Of special interest in connection with the study of the fishes of the United States, is a series from Cuba, contributed by Professor Poey, of

Havana. This gentleman has contributed more than two hundred species, and others have been promised.

The fish of Bermuda, collected by Mr. Goode, also tend to complete the list of the Atlantic species. Dr. John Edward Gray has presented a large number of species of fish, particularly from the Indian Ocean.

Of the fishes from the interior of of the United States, collections have been made of most of the prominent kinds by Mr. James W. Milner, of the United States Fish Commission, while Mr. George Spangler, of Madison, Indiana, has furnished specimens of the paddle-fish, shovel-headed sturgeon, and other conspicuous varieties.

Of marine invertebrates, such as star-fishes, shells, crustacea, worms, &c., immense numbers were gathered by the fish commission on the eastern coast, and extensive series have also been supplied by Mr. Dall from the Aleutian Islands.

Many plants have been received, including a small but very interesting collection made by the Polaris party in high northern latitudes. In accordance with an arrangement entered into between the Smithsonian Institution and the Agricultural Department some years ago, the plants and insects received at the National Museum are turned over to the last-mentioned establishment for proper care, as rapidly as is consistent with the duty of securing reports upon those collections made by the Government expeditions.

In a similar manner human crania received are turned over to the Army Medical Museum, the object in both cases being to avoid dividing series, by combining all the specimens of the same general class in some one of the various Government establishments in the city.

The collections in paleontology, mineralogy, and geology, as already mentioned, are of great magnitude, and alone have filled many hundred boxes. These represent the most important results of the Government exploring expeditions.

It will be seen, from what has been already mentioned, that the collections made during the year represent an enormous aggregate of material, and one requiring the utmost exertions of the limited force connected with the National Museum, for its proper treatment. Of course a strict record must be kept of everything received; and when the packages are opened and the contents assorted, the work of registering and recording begins. Sometimes this requires the identification of the species; and even the mere manual labor of numbering and labeling every specimen, and marking the corresponding record in the registry-book, is one of very great magnitude.

After the respective collections have been properly investigated, and in many cases elaborate reports written concerning them, the selection of a reserve series for the Museum begins, which are then either placed upon the shelves or packed away for future treatment. The duplicates, which constitute a large percentage of the whole, are set aside for ex-

change with other museums or for distribution to educational institutions.

Special effort is directed on the part of the Smithsonian Institution toward carrying out this feature of the plan in the most thorough manner; and while the distribution thus made in 1873 has been very extensive, that for 1874 will be even greater still.

It is in this particular feature that the National Museum of the United States differs from almost any other in the world, excepting, perhaps, in a single direction only, the Government Geological Museum at Vienna.

In most other museums single specimens only of objects are offered or accepted, especially of such as are new to the cabinet, the labor of digesting the results of great expeditions being accomplished under other auspices, no plan being adopted to utilize any surplus, in any other interest than that of the establishment itself. The British Museum, for instance, which stands at the head of all institutions of this kind, never parts with a duplicate, and is oppressed by the weight of its surplus material, even though in small proportion to the reserve collection.

It is a question whether any museum in the world is in receipt of so great an amount of material as the National Museum at Washington; and were the rule of the British Museum to prevail it would be crushed by the weight of its own riches. The constant effort, however, on the part of the Smithsonian Institution to utilize this material in the interest of science and education, tends to keep down the mass, though it is only at the expense of the incessant activity and constant labor of the Museum force that this object is in any measure accomplished.

In most public museums there is a corps of specialists whose business it is to supervise all the collections received, the British Museum having a large force of such officers. The funds available for the National Museum of the United States do not authorize the appointment of such officers, although some of the present assistants are prominent specialists in certain branches. In order, therefore, to secure the prompt determination of the material received, and the consequent speedy disposal of the duplicates, the offers of assistance from eminent scientists, so frequently made, are gladly accepted, and the material placed in their hands for investigation. During the year this labor has been performed, always gratuitously, by a number of gentlemen, among whom may be mentioned Prof. E. D. Cope as employed in the investigation of the fossil mammals; Dr. Coues, Mr. J. A. Allen, and Mr. Ridgway on that of the birds; Professor Cope, of the reptiles; Dr. Gill, Professor Goode, and Mr. J. W. Milner, of the fishes; Mr. P. R. Uhler, Mr. William H. Edwards, Dr. A. S. Packard, Mr. Cyrus Thomas, and Dr. L. Le Conte, of the insects; and Mr. William G. Binney and others, of the shells.

Professor Verrill has undertaken the determination of the collection of marine invertebrates obtained from the waters of the east coast of the United States, with the assistance of Mr. S. J. Smith, Dr. Packard,

Professor Hyatt, and other gentlemen, while Prof. D. Eaton has identified the marine plants. To these gentlemen, the thanks of the Institution are due for their extremely valuable services in the connection referred to.

On the transfer of the large number of ethnological objects from the lower hall and the connecting range to the new room in the second story, much space will be gained for the re-arrangement of the zoological collections, and an opportunity will be given for introducing many species which are now necessarily kept elsewhere, for the want of accommodations. It may, however, be proper to state that for the exhibition of the full series of objects now in possession of the Institution, and not including any unnecessary duplicates, much ampler accommodations will be needed than can be had in the building, and if these are to be displayed as they should be it will be necessary at no distant day to provide means for extending the space, either by a transfer of the entire collection to new buildings or by making additions to that of the Smithsonian Institution.

In illustration of this statement, it may be remarked that, of sixty-seven thousand specimens of birds entered in the catalogues of the museum, and of which more than forty thousand are on hand, (the remainder having been distributed,) less than five thousand are mounted and on exhibition, these occupying fully two-fifths of the present hall; the rest are preserved as skins, in chests, drawers, and boxes, and of them fifteen thousand, or three times the number at present on exhibition, require to be displayed for the proper illustration of even American ornithology.

The urgency for additional room is still greater for the mammals. Here, out of some five or six thousand specimens, less than so many hundred are exhibited, the remainder alone being almost sufficient to occupy half of the hall. Of many thousands of skeletons of mammals, birds, reptiles, and fishes, a very small percentage is shown to the public, while exhibition-room to the amount of thousands of square feet is required for specimens that now occupy drawers in side apartments.

Of the very large collection of alcoholic specimens, which constitute the most important material in every public museum, scarcely anything is on exhibition, although the selection of a single series for this purpose is very desirable.

The new ethnological gallery, already referred to, even now is scarcely adequate to accommodate a complete series of the ethnological specimens on hand, without taking into consideration the number that the explorations of the past few years may lead us to expect for the future.

It is, however, very gratifying to be able to state, that if the proper plan of a national museum for the United States should be to make it an exponent of the ethnology, and of the animal, vegetable, and mineral treasures of America, this can be considered as in a great measure already accomplished, especially for North America, and to a very con-

siderable degree for the middle and southern portions of the New World. All that is now required by the Institution for the presentation of such a series is proper accommodations and the means necessary to prepare and exhibit the same.

With the vast number of duplicates on hand it is always easy to secure, in the way of exchange with foreign collections, nearly all the objects desired from other parts of the world, and it will probably never be necessary to ask for funds, to any extent, to secure such articles by purchase—an expense which constitutes the principal outlay of most foreign museums.

Mineralogical Collection.—The following is an account of the mineralogical department, by Dr. F. M. Endlich, who has charge of this branch of the museum:

The mineralogical department of the United States National Museum (placed by Congress under the charge of the Smithsonian Institution) comprises four divisions:

I. Mineralogy.
II. Lithology.
III. Ores.
IV. Metallurgy.

The collection of minerals occupies twelve cases, and numbers upwards of 3,000 specimens, belonging to 230 species. These minerals are collected from all parts of the globe, obtained to a considerable extent from the United States Government expeditions, and by exchange and donations. Dana's system of mineralogy has been chosen to serve as a basis for the arrangement of the different species and groups, and, in order to render the collection of use to the visitor or student, a very elaborate system of labelling has been adopted. Every specimen, unless too large, is placed in a paste-board tray, which contains, at the same time, a label giving the name of the mineral, the chemical composition, crystalline form, if any, locality, and the name of the donor. At the beginning of each species in the continuous row is placed a printed "species-label," giving the name and chemical composition, and distinguished from the rest by a red border. To the front edge of its tray every specimen has attached a printed label with black border, showing the name and locality. In case the mineral is not contained in a tray this label is placed in some conspicuous position near it. The printed labels are so distributed as to be easily read by the visitor, at the same time disposed in such a manner as not to obstruct the view of the specimen. Large printed "division-labels" are placed at the head of each of the six divisions adopted by Professor Dana.

This system of labelling will enable the student to see at once the name, composition, and locality of any mineral, and will show him its position in the adopted system of classification. Besides these precautionary measures, to preserve the history of every individual specimen, a number is written on every specimen, corresponding to one in the mineral record, in which the labels are entered.

Several very rare and valuable specimens of meteoric iron and other minerals are contained in the collection. In the appendix is given an alphabetical list of species at present represented in the museum. The enumeration of the species is based upon the catalogue of minerals published by the Smithsonian Institution in 1863.

The lithological collection occupies thirteen cases, and comprises about 2,300 specimens. Of the various species and variety of rocks thus far known and described the greater part is represented. An arrangement has been temporarily adopted by which the specimens are arranged according to their collector, at the same time, however, retaining a certain lithological classification. A large quantity of these specimens has been brought in by the expeditions exploring the Western Territories, and thus a very valuable and unique collection has resulted.

A full suite of Saeman's (Paris) rocks is contained in the collection, besides a suite from Freiberg, Saxony, and other European specimens. Eventually the collection is to be arranged according to locality, following, within these bounds, some definite lithological system. A system of labeling analogous to that adapted for the minerals will be introduced. The size of the lithological specimens is that of similar ones in a large number of European collections—3 inches by 4 inches—giving the collection a pleasing, uniform appearance, and facilitating the arrangement.

Three cases are occupied by the collection of ores, which comprises about five hundred specimens. The object of this collection is to present a characteristic specimen of ore from every worked lode in the Western States and Territories. Every year comparatively large additions are made. These ores are labeled, giving the name, the value as ore, (if known,) the name of the mine, its locality, and the name of the donor. If this collection be completed successfully it will prove to be a very valuable addition to the mining statistics, and will justly illustrate the mineral wealth of the United States.

A collection of metallurgical products has been organized, proposing to show the ores, fluxes, slags, raw and commercial products, illustrating the various processes in operation in the United States and other countries. As yet this collection is small, but it may be hoped that as soon as its existence and object becomes more generally known, the necessary contributions of specimens will not be wanting.

Besides these collections, representing typical specimens, the museum contains a very complete and handsome series of the geyserites and other similar deposits from the United States National Park. Series illustrating various localities famous for their yield of minerals, such as Wieliczka, in Polish Austria, Girgenti, in Sicily, and others, have been obtained. The mineralogical and geological material collected and rescued by the North Polar Expedition, under the late Captain Hall, forms one of these interesting suites.

Altogether there are upward of 6,300 specimens on exhibition; over 800 are on hand, to be incorporated during the present year, and almost daily new material swells the collection.

In connection with the mineralogical department is the mineral exchange. A large number of mineral duplicates, upwards of 10,000, is on hand, and these, having been classified and arranged in series, will be distributed to institutions of learning or disposed of in exchange in order to increase the main collection. A limited number of good duplicates is kept on hand—deposited in drawers—to serve for foreign exchange and to afford material for study, should it be required.

Photographs of antiquities in the British Museum.—Among the additions to the museum is a series of photographs of the most valuable contents of the British Museum, systematically made and arranged with the definite object of showing man's gradual advance and the development of civilization from pre-historic to mediæval times. These were made by S. Thompson, with the consent of the trustees of the museum, for W. A. Mansell & Co., of London, as proprietors, and have in part been presented by them to the Institution. The series consists of nearly a thousand plates and is grouped in seven parts:

I. Pre-historic and ethnographical series.
II. Egyptian series.
III. Assyrian series.
IV. Grecian series.
V. Etruscan and Roman series.
VI. Antiquities of Britain and foreign mediæval art.
VII. Seals of sovereigns, corporations, &c.

They will be placed on exhibition at the Institution in the large hall as soon as the cases are prepared to receive them. These photographs are a valuable contribution to the means of diffusing a knowledge of the largest ethnological collection in the world, and will serve as original materials for the use of the historian, scholar, and art-student. The publication of a work of this magnitude has necessarily caused an enormous outlay, and the proprietors are obliged to seek the support of men of culture, for whom it has been prepared. It gives us pleasure to recognize the importance to art and science of this new application of photography, and to recommend it to public institutions and gentlemen of fortune. It is not necessary to point out how valuable such a work would be to any library or museum, particularly in a country where but few can have the opportunity of seeing and still fewer that of studying the originals represented.

CORRESPONDENCE.

An immense amount of labor is every year devoted to correspondence, which includes subjects relating to almost every branch of human

thought. Among the communications are many which relate to supposed scientific discoveries and proposed new theories of the physical phenomena of the universe.

There exists, especially in this country, in which there is a greater amount of popular diffusion of scientific knowledge than in any other, a class of persons who, without previous scientific training, attempt to solve the most difficult problems of general physics. Among these are men of considerable literary culture and much general reading, but wanting in the special kind of logical and mathematical training necessary for successful scientific investigation, they dissipate a large amount of mental energy in unproductive speculations. The correspondence with this class of persons is not only very onerous, but difficult to manage, inasmuch as the rejection of their propositions is generally attributed to prejudice or a kind of scientific oligarchy. The general method which has been adopted for dealing with them is to insist upon their deducing from their hypotheses some new results which can be immediately verified by experiment and observation, as a test of the value of their speculations. This demand is made on the ground that any hypothesis of value must not only explain what is already known, but must also lead to results which have not previously been observed.

Another class of correspondents write for information as to scientific principles on which to found inventions for special purposes. Among this class we have had within the last few years a large number of gentle men of intelligence in the Southern States, who seek to retrieve fortunes lost in the war by inventions which may become remunerative through the sale of privileges for using them. Unfortunately, in most cases the problems they essay are of too expensive a character to be brought to the test of experience without the outlay of a large amount of money, and frequently of too indefinite a conception to warrant success even under the most favorable circumstances. The most remunerative inventions are those of very simple character, and of general use, such as a sewing-machine, rather than a steam-engine.

Another class of correspondents consists of those who ask for the information as to minerals, plants, and other objects of natural history. In the answers to these the Institution has done great service in the assistance of students, and in the diffusion, unostentatiously, of a large amount of knowledge.

In carrying on the correspondence and other parts of the general operations of the establishment, much assistance has been rendered by the collaborators of the Institution, among whom, during the past year, our thanks are due to Prof. S. Newcomb, Prof. W. Harkness, and Prof. Asaph Hall, of the Naval Observatory; Prof. J. E. Hilgard, C. A. Schott, and Prof. William Ferrel, of the Coast Survey; Dr. Woodward and Dr. Otis, of the Army Medical Museum; Prof. J. P. Lesley and W. E. Dubois, of Philadelphia; Prof. W. D. Whitney and Prof. J. D. Dana,

of New Haven; J. H. Trumbull, of Hartford; Prof. F. L. O. Roehrig, of Ithaca, New York; Dr. Henry Wurtz and Prof. Raymond, of New York; Dr. L. D. Gale, Edw. Clark, esq., W. Q. Force, Prof. C. Abbe, of Washington, and others, especially in natural history, mentioned in connection with the operations of the museum.

WORK DONE IN THE INSTITUTION AND IN CONNECTION WITH OTHER ESTABLISHMENTS.

The Secretary, in addition to the general direction of the scientific operations of the Institution, has continued during the past year his investigations in regard to fog-signals and other aids to navigation, and has discharged the duties of chairman of the Light-House Board, visitor to the Government Hospital for the Insane, president of the National Academy of Sciences, and trustee of the Corcoran Art Gallery.

Professor Baird, the assistant secretary, in addition to the arrangement of the materials received by the museum, making up duplicates for distribution, and the general direction of the system of exchanges, has continued the duties with which he was charged by the President of the United States in accordance with the law of Congress, namely, that of prosecuting an inquiry into the present condition of the fisheries of the coast and lakes, and the suggestion of methods for their improvement. As in 1871 and 1872, he spent the principal part of the summer season in carrying on his mission. He established himself on Peak's Island in Portland Harbor, where, with a large force of volunteer naturalists, he was engaged from July until October.

The law of Congress under which his work is carried on directs the departments of the Government to render him all the aid in their power, and in pursuance of this the Secretary of the Navy placed at his disposition the United States steam-tug Blue Light, under Commander L. A. Beardslee, United States Navy, properly fitted for her purposes and provided with all the apparatus necessary for deep-sea research; and with the co-operation of Prof. A. E. Verrill, an eminent zoölogist of Yale College, his associate in this work, he succeeded in solving many of the problems of the inquiry, as well as in securing at the same time a great amount of material in the way of specimens of marine animals for the National Museum, embracing a very large number of species, among them numerous forms entirely new or previously unknown on our coast.

In addition to the examination and classification of the minerals which have been received at the Institution, and making up sets for distribution, Dr. Endlich has made a qualitative examination of a large number of specimens of minerals which have been submitted for that purpose to the Institution. For purposes of education the Institution furnishes qualitative determinations of mineralogical specimens, but in no case will it undertake to furnish percentages of the different components of

specimens, or give certificates for commercial purposes of their value. In regard to work of this class, the following rules have been adopted:

1. All applications for the examination of specimens must be made by letter, addressed "Secretary of the Smithsonian Institution."

2. The specimens examined, or a part of them, will be retained by the Institution.

3. All specimens are to be delivered to the Institution free of expense.

Mr. Meek, who still retains his connection with the Smithsonian Institution, has continued during the past year his palæontological investigations relative to the specimens collected by various State and General Government surveys. He spent last summer in Colorado in the investigation of the geology of the region, returned to Washington in October, but on account of the weak condition of his lungs he thought it prudent to spend the present winter in Florida, carrying with him a part of his library and a series of specimens with which to continue his work.

Dr. Theodore Gill, who has special charge of the Smithsonian deposit in the Library of Congress, and devotes his extra time in the Institution to natural history, has been engaged during the past year in the study of the vertebrates generally, the results of which have been partially published in a memoir on the number of classes of vertebrates and their natural relations. He has also revised the nomenclature of the marine fishes of our eastern coast from Greenland to Florida, and prepared a catalogue of them for the report of the United States Commissioner of Fish and Fisheries, and has, at the request of the same officer, investigated the genus *Micropterus*, comprising the black-bass, &c., and definitely established its species and nomenclature.

The Institution in 1870, fitted up a photographic apartment, under the charge of Mr. T. W. Smillie, in which photographs are taken of specimens of archæology and of natural history for illustrating the publications of the Institution, and for distribution to other museums. During the past year a large number of food-fishes and prehistoric remains have been photographed.

The specimens of the Institution are open to all investigators for study, and no work of importance on natural history has been published within the last twenty years in this country which has not been indebted to this establishment for the use of materials and other facilities in its production. The same privilege has been granted, under certain restrictions, to the officers of the Institution, and Professor Baird has availed himself of this by employing his leisure time for several years in the production of an extensive work on North American ornithology. In this enterprise Professor Baird has associated with himself Dr. Thos. M. Brewer, of Boston, and Mr. Robert Ridgeway, of Illinois. The work is published by Messrs. Little & Brown, of Boston, who have printed

three volumes, quarto size, embracing the land-birds. A second part, that on the water-birds, is in an advanced state of preparation, and the whole will be published within the year 1874. The work is fully illustrated by engravings finely executed in wood-cuts and in colored plates, and it is believed will meet a want long felt and expressed as to a manual of American ornithology.

CONCLUSION.

From the foregoing statements it will be evident that the Institution is still in a prosperous condition; that it is continually increasing in usefulness and reputation; that, although the current operations will be somewhat impeded during 1874 by the failure of the First National Bank, yet the effect of this loss will be but temporary; and that, with the appropriation from Congress for the care of the museum, the legitimate objects of the Institution can be prosecuted with more energy than heretofore.

Respectfully submitted.

JOSEPH HENRY,
Secretary.

WASHINGTON, *January*, 1874.

APPENDIX TO THE REPORT OF THE SECRETARY.

Table showing the number of entries in the record-books of the Smithsonian Museum at the close of the years 1872 and 1873, respectively.

Class.	1872.	1873.
Skeletons and skulls	12, 450	13, 290
Mammals	11, 195	11, 625
Birds	62, 718	65, 950
Reptiles	7, 729	8, 222
Fishes	9, 758	12, 514
Eggs of birds	16, 322	16, 710
Crustaceans	2, 187	2, 194
Mollusks	24, 792	24, 792
Radiates	3, 107	3, 139
Annelids	100	100
Fossils, invertebrate	7, 715	7, 725
Minerals	7, 167	8, 108
Ethnological specimens	11, 609	13, 084
Total	176, 749	187, 453

Increase for 1873 10,704

Approximate table of distribution of duplicate specimens to the end of 1873.

Class.	Distribution to the end of 1872.		Distribution during 1873.		Total to end of 1873.	
	Species.	Specimens.	Species.	Specimens.	Species.	Specimens.
Skeletons and skulls	344	864	45	250	389	1, 114
Mammals	963	1, 890	75	1, 100	1, 038	2, 990
Birds	24, 069	37, 095	511	790	24, 580	37, 885
Reptiles	1, 841	2, 970	134	250	1, 975	3, 220
Fishes	2, 517	5, 398	200	350	2, 717	5, 748
Eggs of birds	6, 627	16, 720	49	50	6, 676	16, 770
Shells	84, 617	187, 192	20	100	84, 637	187, 292
Crustaceans	1, 078	2, 650	......	....	1, 078	2, 650
Radiates	583	778	......	....	583	778
Other marine invertebrates	1, 844	5, 160	......	....	1, 844	5, 160
Plants and packages of seeds	20, 370	29, 705	3, 000	10, 000	23, 370	39, 705
Fossils	4, 112	10, 141	......	....	4, 112	10, 141
Minerals and rocks	5, 313	10, 702	140	450	5, 453	11, 152
Ethnological specimens	1, 676	1, 739	210	230	1, 886	1, 969
Insects	2, 248	4, 294	500	2, 000	2, 748	6, 294
Diatomaceous earths	58	662	25	150	83	812
Total	158, 260	317, 960	......	....	163, 169	333, 680

ADDITIONS TO THE COLLECTIONS OF THE SMITHSONIAN INSTITUTION (UNITED STATES NATIONAL MUSEUM) IN 1873.

Abbott, Chas. C.—One bottle specimens, fish, (*Hybognathus osmerinus,*) from Trenton, N. J.

Addison, Mr.—Skin of plover (*Charadrius Azaræ*) from Brazil.

Agassiz, Prof. Louis.—(See under *Cambridge.*)

Aiken, C. E.—A collection of birds from Colorado.

Alcorn, Hon. J. L.—One Indian pipe from Coahoma County, Miss.

Alden, George J.—Skins of blue heron (*Florida cærulea*) and avocet (*Recurvirostra americana*) from Manatee, Fla.; one specimen (fœtal) of opossum (*Didelphys virginiana*) from New Smyrna, Fla.

Allen, Prof. J. A.—(See under *Washington, War Department, U. S. A., Yellowstone Expedition.*)

Alth, Dr. Alois.—(See under *University of Krakau.*)

Ames, James T.—A collection of minerals from the Chester, Mass., emery-mines.

Anderson, H. G.—One box of minerals from Wisconsin.

Anderson, W.—Indian stone implements from Brownsville, Ohio.

Andrews, Prof. E. B.—A meteorite from Concord, Ohio.

Armitage, J.—(See under *W. F. Wheeler.*)

Ashbaugh, Dr. A.—Five Indian skulls, three stone axes, three pipes, and one stone pestle, from the West.

Atkins, C. G.—Four boxes of fresh fish for casting from Bucksport, Me.

Austin, E. P.—Indian stone implements from Michigan.

Avery, Dr. W. H.—One skin, pigeon hawk, (*Falco columbarius,*) from Greensborough, N. C.

Baird, Prof. Spencer F.—(See under *Washington, Interior Department, United States Commission of Fish and Fisheries.*)

Baker, Isaac C.—One Indian stone implement from Scarborough, Me.

Ball, J. W.—One stone pestle from Ball's Bluff, Va.

Barnum, Phineas T.—Specimens in the flesh of Malayan tapir, (*Rhinochœrus sumatranus;*) Bactrian camel, (*Camelus bactrianus;*) Dromedary, (*Camelus dromedarius;*) African panther, (*Felis, sp.;*) mandril, (*Cynocephalus;*) rhinoceros; manatee, (*Manatus americanus;*) and a Shetland pony ten days old.

Barringer, Paul.—Nest and egg of blue yellow-backed warbler (*Parula Americana*) from Mebanesville, N. C.

Batty, J. H.—One mounted specimen ruffed grouse (*Bonasa umbellus*) from Bloomfield, N. Y.; two boxes of birds from New York. (See also under *Washington, Interior Department, United States Geological Survey.*)

Belknap, Commodore G. E., United States Navy—(See under *Washington, Navy Department, Bureau of Navigation.*)

Bendire, Capt. Chas., United States Cavalry.—One box of birds' nests and eggs, from Arizona.

Bessels, Dr. Emil.—(See under *Washington, Navy Department, Polaris expedition.*)

Bissell, Geo. R.—Specimen of hair-worm (*Gordius, sp.*) from Irondale, Mo.

Blaine, John E.—One box of minerals from Montana.

Blossom, J. B.—One box of salmon from Bathurst, N. S.

Blunt, Capt. A. P., Quartermaster's Department, United States Army.—Head and horns of mountain sheep, (*Ovis montana.*)

Boardman, Geo. A.—One box of salmon from Calais, Me.; one bird-skin.

Boisnuier, Edward.—One box of white-fish from Sandwich, Ont.

Bonsall, J. Vincent.—One box of minerals from Rising Sun, Md.

Booth, H.—Shells from the west coast of North America.

Boyd, S. H.—Specimens of crude salt from Lincoln, Nebr.

Bradley, Prof. F. H.—(See under *Washington, Interior Department, United States Geological Survey.*)

Breed, E. E.—Eggs of duck-hawk (*Falco anatum*) from Embarrass, Wis.

Brendel, F.—A collection of plants from Peoria, Ill.

Benner, Franklin.—Skins of laughing gull (*Larus atricilla*) and Tern (*Sterna bairdii*, n. s.) from Portland, Me.

Brooks, T. B.—One box of minerals from Marquette, Mich.

Bryan, O. N.—Human bones from mounds in Iowa; stone implements from Maryland.

Cambridge, Mass., Museum of Comparative Zoology, (Prof. Louis Agassiz.) A series of casts of the crania of *Mastodon giganteus* from the Wyman series.

Campbell, Archibald.—(See *Washington, northern boundary survey.*)

Carpenter, Capt. W. L., United States Infantry.—(See under *Washington, Interior Department, United States Geological Survey.*)

Case, J.—Quartz arrow-heads from Troy, Pa.

Case, R. A.—One box of birds' eggs from North Lawrence, Kans.

Casey, T. L., jr.—Collections of shells from Florida and Cuba.

Caton, Hon. J. D.—Skins of mule-deer, (*Cervus macrotis;*) black-tail deer, (*Cervus Columbianus;*) and hybrid deer, from his park in Ottawa, Ill.; specimens of petrified wood from California.

Cheney, Simeon F.—Skeleton of sea-seal (*Erignathus barbatus*) from Grand Manan, N. B.

Chicago, Academy of Sciences, Dr. J. W. Velie.—Twelve eggs of "man-of-war bird," (*Tachypetes aquila.*)

Christ Church, New Zealand, Canterbury Museum, Dr. Julius Haast.—A collection of bird-skins; a collection of stone implements of the Moa hunters; a collection of *Dinornis* bones from Kjoekken-moeddings; complete skeletons of *Dinornis giganteus* and *Palapteryx elephantopus*,

and the leg-bones of *Dinornis gracilis*, *Dinornis casuarius*, and *Dinornis didiformis*, all from New Zealand.

Clark, Dr. E. J.—One Indian stone maul.

Clark, John M.—Specimens of Indian pottery from Milledgeville, Ga.

Clarke, Stephen.—One box of minerals from Virginia.

Clements, Mr., United States surveyor-general for Utah.—One package of ores from Utah.

Coe, W. W.—Nest and skin of warbling fly-catcher (*Vireo gilvus*) from Portland, Conn.

Cole, Seward.—One seal-gut coat from Alaska.

Coleman, Geo. S.—One specimen of clay from Kosse, Tex.

Cooper, Dr. J. G.—One box of bird-skins from California.

Cooper, W. A.—Skins of king-bird (*Ceryle alcyon*) and Cassin's fly-catcher, (*Tyrannus vociferans*,) and eggs of Gairdner's woodpecker, (*Picus Gairdneri*,) and chestnut-backed tit, (*Parus rufescens*,) from Santa Cruz, Cal.

Copley, Charles L.—Two tanks of fishes in alcohol from Tompkinsville, Staten Island, N. Y.

Coues, Dr. Elliott, United States Army.—Bird-skins from Arizona; skins, skeletons, and skulls of mammals; birds from Fort Randall. (See also *Washington; Department of State; Northern boundary survey.*)

Cowdrey, Dr. S. G., United States Army, (through Army Medical Museum.)—Cast skin of black-snake (*Bascanion constrictor*) and rattles of rattlesnake (*Caudisona confluenta*) from Fort Larned, Kansas.

Crawford, J. A.—Indian pottery from Davenport, Iowa.

Cushman, Doctor.—Indian stone implements from Wiscasset, Me.

Dall, Wm. H., Coast Survey U. S. A.—Twenty-seven boxes and kegs of general zoological and ethnological collections from the Aleutian Islands.

Day, Mr.—Specimens of sandstone and lignite from Maryland.

Delaney, Hon. John, postmaster-general of Newfoundland.—Bones of (*Phoca, sp.*) and great auk, (*Alca impennis;*) two bottles specimens of capelin (*Mallotus villosus*) from St. John's, Newfoundland.

Dille, I.—Specimens of tourmaline and lignite from Washington, D. C.

Douglas, Charles.—Two specimens, in the flesh, of evening grosbeak (*Hesperiphona vespertina*) from Waukegan, Ill.

Ebaugh, David.—One box of minerals from Maryland.

Edmunds, M. C.—Specimens of smelt (*Osmerus, sp.*) from Lake Champlain.

Edwards, Vinal N.—(See under *Washington; Interior Department; United States Commission of Fish and Fisheries.*)

Elliott, Henry W., special agent Treasury Department United States.—Five boxes of bird-skins, nests, and eggs from the Prybilov Islands, Behring Sea.

Elliott, Capt. Jas.—One specimen flying-fish (*Exocœtus, sp.*) from Brazil.

Endlich, Dr. F. M.—A collection of minerals from Europe. (See also

under *Washington; Interior Department; United States Geological Survey.*)

Evans, W. W.—One box of pottery and silver articles from Peru.

Feuchtwanger, Dr. Louis.—One box of minerals.

Fitzhugh, D. H.—Specimens of grayling (*Thymallus tricolor*) from Au Sable River, Michigan.

Foreman, Mrs.—Chipped flints from Hot Springs, Arkansas.

Fortin, P.—One skin cod-fish (*Gadus morrhua*) from Canada, (type of *Gadus ductor*, Fortin.)

Frellick, Capt. John.—One specimen sea-horse (*Hippocampus, sp.*) from Saint George's Banks.

Fuller, A. N.—Two nests and six eggs Bell's fly-catcher (*Vireo Belli*) from Lawrence, Kans.

Gabb, Prof. William M.—Seven boxes general collections from the Talamanca expedition, Costa Rica.

Garland, William H.—A specimen in the flesh of western red-tailed hawk (*Buteo calurus*) from Amherst County, Virginia.

Gatch, S. H.—One package of plants from Oregon.

Giles, Norwood.—One box of birds' nests from Wilmington, N. C.

Gizer, B. F.—One Lepidopterous larva from Stoyestown, Pa.

Glover, Lieut. Russell, United States Revenue-Marine.—Fossil-shells from vicinity of Baltimore, Md.

Goode, G. Brown.—(See under *Middletown; Museum of Middletown University;* also under *Washington; Interior Department; United States Commission of Fish and Fisheries.*)

Gorman, Cook.—One box of minerals from Talladega County, Alabama.

Gray, Dr. John Edward, British Museum.—A collection of fishes.

Green, H. A.—One specimen of arragonite from Atco, N. J.

Green, Seth.—One box of fish from Rochester, N. Y.

Haast, Dr. Julius.—(See under *Christ Church, Canterbury Museum.*)

Hale, Dr. J. D.—One Indian arrow-head from Fentress County, Tennessee.

Hamlin, Dr. A. C.—One specimen of meteorite from Searsmount, Me.

Hammond, Dr. John F., United States Army.—Two alleged asses' skulls from Texas.

Hanna, George B.—One box of minerals from North Carolina.

Hardenburgh, L. R., United States surveyor-general for California.—Ten packages of minerals from California.

Harford, G. H.—One box of ethnological specimens from California.

Harrington, C.—One egg of blue-tailed kite (*Rostrhamus sociabilis*) from Florida; one egg of Allen's towhee, (*Pipilo Alleni.*)

Harris, N. H.—One box of minerals from Claiborne County, Mississippi.

Hays, W. W.—One skin of rail (*Rallus Virginianus*) from San Luis Obispo, Cal.

Heaton, J. C.—One specimen of beetle from Victoria, Tex.

Henshaw, H. W.—(See under *Washington; War Department; United States Army surveys west of the one hundredth parallel.*)

Holden, Prof. William.—(See under *Marietta; Marietta College.*)

Hollenbush, H. W.—One large stalactite from Crystal Cave, Berks County, Pennsylvania.

Hoopes, William A.—Specimens of native silver from Isle Royale, Mich.

Homer, Dr. Frederick, United States Navy.—A branch of a tree injured by hail.

Hough, Dr. F. B.—One box of ethnological specimens.

Howard, A. M.—Specimens of Indian pottery from New Mexico.

Hurlbut, G. H.—One skeleton of pinchaca or danta, (*Tapirus pinchaque,*) one banana in alcohol from Costa Rica; two boxes of bird-skins from Bogota.

Jewett, Col. E.—One box of ethnological specimens from Florida.

Johnston, C. E.—One specimen of horned toad (*Phrynosoma, sp.*) from Saint George, Utah.

Kelly, F. X.—One nest of tarantula spider.

Kelly, Robert.—One specimen of pyrite.

Krakau University, Dr. Alois Alth.—A series of minerals from the Wieliezka salt-mines.

Lanman, Chas.—A collection of minerals from Virginia.

Leaming, Dr. F.—One cast of Indian stone implement from Jefferson County, Indiana.

Lee, Mary J.—A collection of minerals from Bremond, Tex.

Leonard, H. L.—One box of land-locked salmon, (*Salmo sebago,*) fresh specimens, from Lubec Pond, Maine.

Lente, W. K.—A collection of bird-skins from the West Indies.

Lockhart, W. T.—One specimen of cinnabar from Oakville, Cal.

Love, W. C.—Specimens of fossil-shells from Marlborough, Md.

Ludington, C.—Specimens of oyster (*Ostræa Virginianus*) from the Potomac River.

Lupton, S. R.—A collection of minerals from West Virginia.

Lyon, Hon. Caleb.—One package of eggs.

McFarlane, R., Hudson Bay Company.—Skin of fœtal eight-legged beaver (*Castor Canadensis*) from Fort Simpson, Hudson Bay Territory.

McKinley, William.—Ancient Indian funeral-urn from Milledgeville, Ga.

McRae, John, Hudson Bay Company.—One skin of black marmot (*Arctomys monax,* melanistic) from Athabasca.

Mains, M. P.—One box of fossils from Bull River, S. C.

Marietta, O., Marietta College, Prof. William Holden.—A collection of reptiles and fishes from Eastern Ohio, (deposited.)

Marshall, U. S.—(See under *W. F. Wheeler.*)

Marvin, A. R.—(See under *Washington, Interior Department, United States Geological Survey.*)

Maynard, C. J.—Sternum of martin (*Progne subis*) from Massachusetts.

Meigs, Gen. M. C.—Spoons made of buffalo-horn from the Yellowstone, one package of Indian implements from Arizona, skin and head of mule-deer, (*Cervus macrotis,*) one Indian stone-chisel, a collection of cretaceous fossils from Heart River, Mo., a specimen of *terebratula, sp.*, from Ingleton, Ala., two packages of seeds of the "sujaro," or giant cactus, from Arizona.

Merriam, C. Hart.—A collection of birds from Florida, six skins of pine-creeping warblers, (*Dendrœca pinus,*) from Florida. (See also under *Washington, Interior Department, United States Geological Survey.*)

Middleton, Carman & Co.—(See under *Washington, United States Commission of Fish and Fisheries.*)

Middletown, Conn., Museum of Middletown University, G. Brown Goode.—A collection of fishes from the Bermuda Islands, a collection of minerals from Connecticut. (See also under *Washington, United States Commission of Fish and Fisheries.*)

Moore, C. R.—A living specimen of salamander (*Amblystoma vigrinum*) from Johnstown, Va.

Moore, Col. James M., United States Army.—Skin of puma (*Felis concolor*) from Wyoming Territory.

Moore, W. H.—A collection of fossils from Topeka, Kans.

Moses, F. K.—One Indian stone implement, from Bucksport, Me.

Mann, Archibald.—The jaws of giant cuttle-fish (*Octopus*) from Newfoundland.

Minn, Dr. C. E., United States Army.—Specimens of infusorial earth, Fort Woodworth, D. T.

Moreno, President, (through Hon. Rumsey Wing.)—Skeleton and mounted skin of pinchaca (*Tapirus roulini*) from Ecuador.

Newman, Joseph, (through Department of Agriculture.)—Arrow-heads, from Woodlawn, Md.

Nichols, Dr. C. H., Government Asylum for the Insane.—A fresh specimen of European tame swan.

Ogden, Mr.—One bottle of insects from New Orleans.

Ogle, David G.—Minerals and ethnological specimens from Maryland.

Oudesluys, C. L.—Specimens of asbestos from Virginia and Maryland.

Owsley, Dr. J. B.—Specimen of fossil-wood from Butler County, Ohio.

Packard, Dr. A. S.—(See under *United States Commission of Fish and Fisheries.*)

Paine, W. W.—Sword, &c., from the wreck of the British vessel Rose, in the Savannah River, Ga.

Palmer, Edward.—(See under *United States Commission of Fish and Fisheries.*)

Pattison, H. A.—One box of fossils from Flint River, Ala.

Patton, A.—Ethnological specimens from Indiana.

Paxton, Capt. J. W., (through J. W. Milner.)—Ethnological specimens from Alpena, Mich.

Peale, Dr. A. C.—(See under *Washington, Interior Department, United States Geological Survey.*)

Peck, P. P.—Fossil shark's teeth from Richmond, Va.

Peelor, David.—Specimens of stickle-back (*Gasterosteus, sp.*) from Johnstown, Pa.

Perrine, T. M.—Photographs and casts of Indian implements.

Pickett, John T.—Cast of fossil (*Cucullæa gigantea*) from the Eocene of Montgomery County, Ala.

Pike, Capt. Nicholas, United States consul.—A collection of shells from Mauritius.

Plummer, E. J.—Specimens of silver ores from California.

Poey, Prof. Felipe, University of Havana.—One keg of alcoholic fishes and one box of skeletons of fishes from Cuba.

Powell, Samuel.—One specimen of file-fish (*Monacanthus setifer*) and other fishes, and eggs of *Raia*, from Narragansett Bay.

Powell, Maj. J. W.—(See under *Washington, Interior Department, Smithsonian Institution.*)

Putnam, J. D.—One box of insects from Iowa.

Quarles, B. M.—Specimens of calcite from Healing Springs, Bath County, Va.

Ray, G. E.—A collection of minerals from Arkansas.

Reeder, H. J.—Specimens of fish (*Percopsis guttatus*) from vicinity of Easton, Pa.

Reese, J. W.—Specimens of bark from Visalia, Cal.

Rhees, W. J.—Specimens of lignite from Fourteenth-street road, Washington.

Rhoads, Dr. F.—Two specimens of fish (*Dorosonia cepedianum*) from Shawneetown, Ill.

Rhoads, Thomas.—One box of ethnological specimens from Ohio; one skin of Savannah sparrow (*Passerculus savanna*) from Florida.

Ridgway, Robert.—A collection of birds and a specimen of mole (*Scalops argentatus*) from Mount Carmel, Ill.; specimens of *Dermestes, sp.*

Rinker, James T.—One insect.

Robertson, M. B.—One box of ores from Lynchburgh, Va.

Robertson, R. S.—One box of Indian bones from mounds in Fort Wayne, Ind.

Rockwell, H. E.—Specimens of vermiculite from Millbury, Mass.

Rothrock, Dr. J. T.—(See under *Washington, War Department, United States Army surveys west of the one hundredth parallel.*)

Royal College of Surgeons, London, England.—A mounted skeleton of jackal (*Canis aureus.*)

Rusk, Hon. T. M.—One box of minerals from Virginia.

Rutter, H.—One box of fish from Fredericton, N. B.

Saint Paul, Minn., Academy of Natural Science.—Eggs of marbled godwit (*Limosa fedoa*) from Saint Paul.

Salisbury Museum, Salisbury, England. W. Blackmore.—Four boomerangs from Australia.

Sanborn, J. K.—Minerals from Vermont.

Sarg, F.—One skin of Honduras turkey (*Meleagris ocellata*) from Honduras.

Scammon, Capt. C. M., United States Revenue Marine.—Seven boxes of cetacean skeletons from the Pacific.

Schlottmann, Dr. A.—One package of insects from Fayette County, Texas.

Schliemann, Dr. Henry.—A plaster-cast of Phœbus Apollo.

Schuermann, Carl W.—Larva of hickory-moth (*Ceratocampa imperialis*) from Fairfax, Va.

Schumacher, Paul.—Ethnological collections from the Kjoekken Moeddings in Oregon.

Seyboth, Robert, United States Signal Service, (through United States Signal Office.)—One specimen of Bohemian wax-wing (*Ampelis garrulus*) in the flesh from Pike's Peak.

Shepard, Prof. C. U.—One box of minerals.

Skillings, Robert F.—Indian stone implements from Peak's Island, Me.

Slamm, Lieut. J. A., United States Revenue Marine.—Collection from shell-heaps, Rogue's Island.

Smith, Isaac D.—Specimens of Tarantula and nest from Arizona.

Smith, S. W.—Specimens of sandstone from Brookville, Pa.

Smith, W. H.—Specimens of mica from Alabama.

Snow, A L.—Indian bones from caves in Eastern Tennessee and West Virginia.

Soriano, M. S.—A series of bismuth ores from San Luis Potosi.

Southwell, J. H.—A collection of arrow-heads from Port Byron, Ill.

Spangler, George.—Three boxes of minerals, fossils, and Indian stone implements from Madison, Ind. Four specimens of shovel-nose sturgeon (*Polyodon folium*) from the Ohio River.

Spencer, Charles W.—One box of birds' eggs.

Stanley, Col. D. S., United States Army.—A living specimen of kangaroo-rat (*Dipodomys ordii*) from the mouth of Powder River. (See also under *Washington, War Department, Yellowstone expedition.*)

Stevenson, James.—One skin of *Neosorex* from Mount Elbert, Colo.

Stille, Caroline B.—A specimen, in the flesh, of cliff-swallow (*Hirundo lunifrons*) from Washington, D. C.

Stone, Livingston.—(See under *United States Commission of Fish and Fisheries.*)

Stuart, James.—One bottle of alcoholic orthoptera from Winnipeg, British America.

Sumichrast, Prof. F.—One skeleton of Baird's tapir, (*Elasmognathus Bairdii,*) one box of reptiles, and two boxes of skins and skeletons of mammals from Tehuantepec.

Swan, James G.—One box of ethnological specimens from Port Townsend, Wash. Terr.

Taylor, Charles M.—One box of minerals from West Virginia; one perforated stone disk.

Thayer, Abbot H.—One skin of Traill's fly-catcher (*Empidonax traillii*) from Brooklyn, N. Y.

Thompson, A. H.—(See under *Washington, Interior Department, Survey of the Colorado.*)

Toner, Dr. J. M.—Specimen of intestinal worm.

Townsend, J. L.—One skin of green finch (*Pipilo chlorura*) from Salt Lake City.

Trefethen, W. S., & Co.—(See under *United States Commission of Fish and Fisheries.*)

Turner, Dr. S. S.—One specimen, in the flesh, of American magpie (*Pica hudsonica*) from Dakota.

Turner, Samuel.—A deformed head of fox squirrel (*Sciurus ludovicianus*) from Mount Carmel, Ill.

Velie, Dr. J. W.—(See under *Chicago Academy of Sciences.*)

Verrill, Prof. A. E.—(See under *Washington, Interior Department, United States Commission of Fish and Fisheries.*)

Vetromile, Rev. Eugene.—A collection of Indian stone implements from Maine and New Brunswick, (deposited.)

Ward, Prof. H. A.—One skeleton of moose, (*Alce Americanus.*)

Washington, D. C.:

Department of State, U. S. A., United States survey of the northern boundary, (Hon. Archibald Campbell, commissioner.)—Zoological, botanical, and ethnological collections, made by *Dr. Elliot Coues*, naturalist of the expedition.

Treasury Department, U. S. A.—(See under the name of *H. W. Elliott.*)

United States Revenue Marine.—(See elsewhere, under the names of *Capt. C. M. Scammon, Lieut. Russell Glover*, and *Lieut. J. A. Slamm.*)

War Department, U. S. A.:

United States Army.—(See under the names of *Gen. M. C. Meigs, Col. D. S. Stanley, Col. James M. Moore, Capt. A. P. Blunt, Capt. Charles Bendire, Capt. W. L. Carpenter.*)

Surgeon-General's Office: United States Army Medical Museum, (Dr. G. A. Otis in charge of division.)—Two Indian jars and one arrow-head from Florida; one Indian spear-head from Madison Barracks, N. Y. (See also under the names of *Drs. J. F. Hammond, James F. Weeds, Elliott Coues, C. E. Munn, S. G. Cowdrey*, and *H. C. Yarrow*, medical officers, United States Army.)

Surveys west of the one hundredth meridian, (Lieut. G. M. Wheeler in charge.)—General zoological and botanical collections,

made by *Dr. H. C. Yarrow*, *Mr. H. W. Henshaw*, and *Dr. J. T. Rothrock.*)

Engineer and Quartermaster's Department: Yellowstone Expedition, (Col. D. S. Stanley in charge.)—Eighteen boxes general zoological, botanical, and geological collections, made by *Prof. J. A. Allen.*

Signal Service, U. S. A.—(See under the name of *Sergeant Robert Seyboth.*)

Navy Department, U. S. A.: Bureau of Navigation, (Commodore Daniel Ammen.)—Specimens of deep-sea dredgings and of water from off the coast of California, United States steamer Tuscarora, *Commander G. Belknap.*

Polaris Expedition, (Captain C. F. Hall.)—Zoological and geological collections from Greenland, made by *Dr. Emil Bessels.*

Interior Department, U. S. A.—Specimens of minerals from California.

General Land-Office.—Iron pipe from Cherokee County, North Carolina. (See also under the names of *Surveyors-General Clements, L. R. Hardenburgh, and John Wasson.*)

United States Geological Survey of the Territories, (Prof. F. V. Hayden in charge.)—Twenty boxes general zoological and geological collections from Wyoming, Utah, and Montana, made by *Dr. A. C. Peale*, *Prof. F. H. Bradley*, and *C. H. Merriam*; thirty boxes from Colorado, by *Dr. A. C. Peale*, *Dr. F M. Endlich*, *A. R. Marvin*, *J. H. Batty*, and *Capt. W. L. Carpenter.*

United States Commission of Fish and Fisheries, (Prof. S. F. Baird commissioner.)—Sixty boxes general zoological collections from Casco Bay, Me., and vicinity, by *Prof. A. E. Verrill*, *G. Brown Goode*, and *Edward Palmer*; nineteen boxes of fish, &c., from the great lakes and the Ohio River, collected by *J. W. Milner*; five boxes of fish from the Sacramento River, collected by *Livingston Stone*; dredgings from the coast of New England, United States steamer Bache, by *Prof. A. S. Packard*; nine boxes of fishes from Wood's Hole, Mass., collected by *Vinal N. Edwards*; three boxes of fish from Norfolk, Va., collected by *W. H. Sibley*; specimens of groper (*Promicrops guasa*) from Florida, and of turbot, (*Rhombus maximus*,) brill, (*Rhombus lævis*,) and sole, (*Solea vulgaris*,) from England, from *Middleton, Carman & Co.*; model of fishing-boat (dory) from Portland, Me.

Smithsonian Institution. Survey of the Colorado, (Maj. J. W. Powell in charge.)—Seventeen boxes of ethnological and geological collections from Southern Utah, made by *Maj. J W. Powell* and *A. H. Thompson.*

Department of Agriculture, (Hon. Frederick Watts, Commis

sioner.)—A collection of African implements; a fresh specimen of lizard from South America; one specimen of arragonite from Suisun, Cal.; a collection of arrow-heads from Charleston, S. C. (See elsewhere under other entries.)

Wasson, John, United States surveyor-general for Arizona.—Six packages of ores from Arizona.

Webb, John S.—One box of shells, minerals, and fossils from Virginia; fangs of banded rattlesnake (*Caudisona horrida*) from Kent's Mill, Va.

Webber, Mrs. F. P., (through Agricultural Department.) One jar of alcoholic reptiles from Marietta, Ga.

Weber, E.—Specimens of minerals.

Webster, T. S.—Two white eggs of blue-bird (*Sialia sialis*) from Troy, N. Y.

Weeds, Dr. James F., United States Army.—A collection of lepidoptera from Fort Randall, Dakota.

Wellborne, W. F.—A collection of minerals from Forest City, Ark.

Wheeler, Lieut. G. M., United States Army.—(See under *Washington, War Department, U. S. A.*)

Wheeler, W. F., United States marshal, and *J. Armitage.*—One skin of mountain sheep, (*Ovis montana.*)

White, N. T.—Minerals from Weldon, N. C.

White, D. Morgan.—Specimens of bitumen from West Virginia.

Wing, Hon. Rumsey.—Specimens from Ecuador.

Wingard, S. C.—Seven specimens of "showtl" (*Aplodontia leporina*) from Olympia, Wash. Ter.

Wood, R. J.—Specimens of copper ore from La Grange, Ga.

Woodman, H. T.—One barrel of oolite from Key West, Fla.

Worth, E. M.—Three bullets from Braddock's battle-ground, Allegheny County, Pa.

Yarrow, Dr. H. C., United States Army.—Three boxes of fish, and a collection of shells, fossil and recent, from Fort Macon, N. C.; Egyptian signet-ring; a necklace of sea-shells from Fillmore, Utah. (See also under *Washington, War Department, Surveys west of the one hundredth parallel.*)

White, Mrs.—Specimens birds' eggs from Mebanesville, N. C.

Whitehand, R. A.—One skin of boa, from South America.

Whitman, G. P.—One box of fish from Rockport, Mass.

Witter, D. R.—One box ethnological specimens from Mansfield, Pa.

Williams, H.C.—Indian arrow-heads from Fairfax County, Va.

Winans, James.—One specimen insect in alcohol from Xenia, Ohio.

LIST OF MINERALS IN THE NATIONAL MUSEUM, 1873.

By Dr. F. M. Endlich.

Albite.
Allanite.
Allophanite.
Alum and *var.*
Amalgam.
Amber.
Amphibole and *var.*
Analcite.
Anatase.
Andalusite.
Anglesite.
Anhydrite.
Anorthite.
Anthophyllite.
Antimony.
Apatite.
Apophyllite.
Aragonite.
Argentite.
Arguerite.
Arsenic.
Arsenopyrite.
Atacamite.
Aurichalcite.
Azurite.
Barite.
Baritocalcite.
Beryl.
Biotite.
Bismuth.
Bitumen.
Boracite.
Borax.
Bromyrite.
Brookite.
Brucite.
Cacoxene.
Calamine.
Calcite.
Cancrinite.
Carpholite.
Cassiterite.
Celestite.
Cerite.
Cerusite.
Cervantite.
Chabazite.
Chalcanthite.
Chalcocite.
Chalcodite.
Chalcopyrite.
Chlorastrolite.
Chlorite.
Chloritoïd.
Chondrodite.
Chromite.
Chrysoberyl.
Chrysocolla.
Chrysolite.
Cinnabarite.
Clinochlorite.
Clintonite.
Cobaltite.
Columbite.
Copiapite.
Copper.
Copperasite.
Coquimbite.
Corundum.
Cryolite
Cryptomorphite.
Cuprite.
Danburite.
Datholite.
Deweylite.
Diamond.
Diallogite.
Diasporite.
Dolomite.
Domeykite.
Embolite.
Enstatite.
Epidote.
Epsomite.
Erubescite.
Erythrite.
Euchroite.
Euphyllite.
Euxenite.
Fergusonite.
Fluorite.
Forsterite.
Franklinite.
Gadolinite.
Galenite.
Garnet and *var.*
Gehlenite.
Geyserite.
Gibbsite.
Glauberite.
Gold.
Gothite.
Graphite.
Greenockite.
Gypsum.
Halite.
Harmotome.
Hauerite.
Hausmannite.
Hauijnite.
Helvinite.
Hematite and *var.*
Hessite.
Heulandite.
Hydromagnesite.
Hydrotalcite.
Hypersthene.
Idocrase.
Ilmenite.
Iodyrite.
Iolite.
Iron, (meteoric.)
Iserite.
Jamesonite.
Kerargyrite.
Kermesite.
Kerolite.
Kyanite.
Labradorite.
Lanarkite.
Lapis lazuli.
Laumontite.
Lazulite.
Leonhardite.
Lepidolite.
Leucite.
Liebethenite.
Limonite.
Linnæite.
Liroconite.
Magnesite.
Magnetite.

Malachite.
Manganite.
Margarite.
Meerschaum.
Meionite.
Melaconite.
Millerite.
Mimetene.
Mineral coal and *var.*
Molybdenite.
Muscovite and *var.*
Natrolite.
Nephelite.
Nitre.
Oligoclase.
Olivenite.
Opal and *var.*
Orpiment.
Orthoclase.
Ozocerite.
Pectolite.
Peridot and *var.*
Pharmacosiderite.
Phlogopite.
Pickeringite.
Picrophyllite.
Pitchblende.
Polybasite.
Prehnite.
Psilomelane.
Pyrargyrite.
Pyrite.
Pyrolusite.
Pyromorphite.
Pyroxene and *var.*
Pyrrhotite.
Quartz and *var.*
Quicksilver.
Realgarite.
Retinite.
Rhodonite.
Rutile.
Sal ammoniac.
Sassolite.
Scapolite.
Scheeletine.
Scheelite.
Schreibersite.
Scorodite.
Serpentine.
Sillimanite.
Silver.
Smaltite.
Smithsonite.
Spinel and *var.*
Spodumene.
Stannite.
Staurolite.
Stephanite.
Stercorite.
Stibnite.
Stilbite.
Strontianite.
Struvite.
Sulphur.
Sylvite.
Tachydrite.
Talc.
Tennantite.
Tetrahedrite.
Thomsonite.
Titanite.
Topaz.
Tourmaline.
Trona.
Turquois.
Vivianite.
Wad.
Wavellite.
Whitneyite.
Willemite.
Witherite.
Wolframite.
Wollastonite.
Wulfenite.
Zincite.
Zircon.
Zoisite.

LITERARY AND SCIENTIFIC EXCHANGES.

Table showing the statistics of the exchanges in 1873.

Agent and country.	Number of addresses.	Number of packages.	Number of boxes.	Bulk of boxes in cubic feet.	Weight of boxes in pounds.
ROYAL SWEDISH ACADEMY OF SCIENCES, *Stockholm:*					
Sweden	30	45	3	22	710
ROYAL UNIVERSITY OF NORWAY, *Christiania:*					
Norway	28	110	6	45	1, 430
ROYAL DANISH SOCIETY OF SCIENCES, *Copenhagen:*					
Denmark and Iceland	35	50	2	15	480
L. WATKINS & CO., *Saint Petersburg:*					
Russia	100	260	8	60	1, 920
FREDERICK MÜLLER, *Amsterdam:*					
Holland	60	180	8	60	1, 920
Belgium	120	220	5	38	1, 216
Total	180	400	......	....	....
DR. FELIX FLÜGEL, *Leipsic:*					
Germany	590	900	47	350	11, 200
Switzerland	70	120	4	30	960
Total	660	1020	51	380	12, 160
GUSTAVE BOSSANGE, *Paris:*					
France	250	270	16	120	3, 840
Algiers	3	6	1	7	210
REALE ISTITUTO LOMBARDI DI SCIENZE E LETTERE, *Milan:*					
Italy	160	180	8	60	1, 920
ROYAL ACADEMY OF SCIENCES, *Lisbon:*					
Portugal	20	25	2	15	480
ROYAL ACADEMY OF SCIENCES OF MADRID:					
Spain	12	50	4	28	740
WILLIAM WESLEY, *London:*					
Great Britain and Ireland	350	470	34	255	8, 160
Egypt	3	8	1	7	210
Cuba	4	12	2	13	400
Cordova	3	9	1	7	210
Buenos Ayres	6	15	3	18	540
Brazil	2	7	1	6	180
Chile	4	9	1	7	210
Government exchanges to German Empire, Prussia, Bavaria, Würtemberg, Baden, Austria, Switzerland, Greece, Norway, Denmark, Holland, Belgium, France, Italy, England, Russia, Portugal, Spain, Chile	19	....	38	230	7, 300
Grand total	1, 856	2, 735	196	1, 476	44, 236

Packages received by the Smithsonian Institution from Europe in 1872 *and* 1873 *for distribution in America.*

Address.	1872.	1873.
ALBANY, N. Y.		
Albany Institute	20	21
Dudley Observatory	36	30
Medical Society of the State of New York	1	7
New York State Agricultural Society	25	32
New York State Cabinet of Natural History	14	6
New York State Library	35	49
New York State University	4	9
Superintendent of Insurance	......	1
Hon. Francis C. Barlow	1	2
Prof. James Hall	20	25
F. B. Hough	1	......
Prof. G. W. Hough	......	1
C. B. O'Callaghan	1	......
ALFRED CENTRE, N. Y.		
Observatory	2	......
ALLEGHENY, PA.		
Allegheny Observatory	4	3
AMHERST, MASS.		
Agricultural College	1	......
Amherst College	1	8
Geological Survey of Massachusetts	1	1
Prof. H. J. Clarke	......	3
Prof. B. K. Emerson	1	4
Prof. C. U. Shepard	......	1
Prof. E. Tuckerman	1	14
ANNAPOLIS, MD.		
Saint John's College	......	1
State Library	......	5
United States Naval Academy	2	3
ANN ARBOR, MICH.		
Geological Survey of Michigan	......	3
Observatory	5	14
University of Michigan	1	8
Doctor Roninger	2	......
Prof. J. C. Watson	2	......
Prof. A. Winchell	6	......
APPLETON, WIS.		
Lawrence University	......	2
ARMSTRONG, IND. T.		
Armstrong Academy	......	3
ASHLAND, KY.		
Agricultural and Mechanical College	1	......
ATHENS, ILL.		
Prof. Elihu Hall	......	1
ATHENS, OHIO.		
Ohio University	1	1
AUGUSTA, ME.		
Commissioner of Fisheries	2	1
State Library	......	4
Hon. Walter Wells	1	......
AUSTIN, TEX.		
Institution for the Deaf and Dumb	......	1
State Library	......	5
BALDWIN CITY, KANS.		
Baker University	......	1
BALTIMORE, MD.		
American Journal of Dental Science	3	1
College of Pharmacy	......	1
Mayor of Baltimore	......	1
Maryland Academy of Science	......	3
Maryland Historical Society	4	5
Maryland Institute	1	1
Mercantile Library	......	3
Peabody Institute	2	11
State Agricultural Society	1	......
University of Maryland	......	1
Dr. J. G. Morris	......	3
Lawrence B. Thomas	1	......
P. R. Uhler	1	......
BARNET, VT.		
Vermont Historical and Antiquarian Society	......	3
BATON ROUGE, LA.		
Institution for the Deaf and Dumb	......	1
State Library	7	2
State University	......	1
Prof. H. Herzel	1	......
BELLEVILLE, CANADA.		
W. J. Palmer	1	......
BLOOMINGTON, ILL.		
Illinois Natural History Society	1	1
BLOOMINGTON, IND.		
Indiana University	......	1
BOISE CITY, IDAHO.		
Territorial Agricultural Society	......	3
BONHAM, TEX.		
State Geological Survey	......	3
BOSTON, MASS.		
American Academy of Arts and Sciences	131	155
American Christian Examiner	2	6
American Social Science Association	1	5
American Statistical Association	9	16
American Unitarian Association	2	6
Association for Improving the Condition of the Poor	......	1
Board of Education	......	1
Board of State Charities	4	5
Boston Athenæum	1	2
Boston Society of Natural History	292	210
Bowditch Library	2	1
Bureau of Statistics of Labor	......	1
Christian Register Association	2	6
City Hospital	1	1
Commissioner of Insurance	......	1
Day School for the Deaf and Dumb	......	1
Good Health Journal	3	4
Gynæcological Society	1	6
Massachusetts Asylum for the Blind	......	1
Massachusetts College of Pharmacy	......	1
Massachusetts Historical Society	8	10

Packages received by the Smithsonian Institution from Europe, &c.—Continued.

Address.	1872.	1873.
BOSTON, MASS.—Continued.		
Massachusetts Institute of Technology	......	1
Mayor of the city of Boston	......	1
Medical Gazette	......	3
Mercantile Library	......	1
New England Historic Genealogical Society	3	4
North American Review	4	......
Perkins's Institution for the Blind	2	2
Public Library of the City	14	23
State Board of Agriculture	11	5
State Library	7	10
Dr. T. M. Brewer	1	1
Edward Burgess	......	1
Dr. David W. Cheever	......	1
Alvan Clarke	......	1
J. S. Clarke	3	2
Dr. Samuel Eliot	......	1
Mr. Hovey	1	......
Dr. S. G. Howe	1	1
Prof. T. Sterry Hunt	......	3
Alpheus Hyatt	1	......
C. E. Norton	1	......
D. J. C. Nott	......	1
Dr. Albert Ordway	1	......
Professor Pickering	1	2
Alfred P. Rockwell	5	2
Prof. W. B. Rogers	1	1
J. Sandford	2	1
S. H. Scudder	5	5
Dr. H. R. Storer	1	......
H. W. Warren	1	2
Thos. H. Webb	1	......
Robert C. Winthrop	1	......
W. C. Woodbridge	......	1
BRATTLEBOROUGH, VT.		
State Lunatic Asylum	1	......
BROOKLINE, MASS.		
Theod Lyman	3	......
BROOKLYN, N. Y.		
King's County Medical Society	......	1
Long Island Historical Society	2	8
Mercantile Library Association	......	1
Statistical Society of Brooklyn	......	2
Thomas Bland	......	3
BRUNSWICK, ME.		
Bowdoin College	3	6
Historical Society	4	6
Prof. P. A. Chadbourne	1	......
BUFFALO, N. Y.		
Buffalo Historical Society	2	4
Buffalo Society of Natural Sciences	......	1
Medical and Surgical Journal	1	3
Society of Natural History	1	1
BURLINGTON, IOWA.		
Iowa Historical and Genealogical Institute	1	......
BURLINGTON, N. J.		
W. G. Binney	5	3
A. Engström	1	1
BURLINGTON, VT.		
Orleans County Society of Natural Sciences	......	28
University of Vermont	3	7

Address.	1872.	1873.
CAMBRIDGE, MASS.		
Cloverden Observatory	1	......
Dana Library	......	3
Harvard College	41	39
Harvard College Observatory	39	41
Herbarium of Harvard College	......	3
Museum of Comparative Zoology	87	64
Philosophical Society	1	......
Alexander Agassiz	12	11
Prof. L. Agassiz	53	54
Dr. T. A. Allen	......	1
J. G. Anthony	......	2
E. Bicknell	1	......
Charles Bryant	......	1
Prof. W. Ferrel	......	1
Prof. Asa Gray	26	18
Dr. H. Hagen	6	6
Dr. T. Lyman	......	2
Dr. G. A. Maack	4	2
Prof. Jules Marcou	14	6
Dr. Albert Ordway	......	1
Professor B. Peirce	......	6
Prof. John B. Perry	1	......
L. F. de Pourtales	......	3
Prof. R. Pumpelly	1	2
Dr. Steindachner	2	......
Sereno Watson	......	2
Prof. J. D. Whitney	7	7
Prof. J. Winlock	......	2
Prof. Jeffries Wyman	4	......
CARLISLE, PA.		
Dickinson College	......	2
Society of Literature	......	1
CARSON CITY, NEV.		
State Library	......	3
CAVE SPRING, GA.		
Institution for the Deaf and Dumb	......	1
CEDAR SPRING, S. C.		
Institution for the Deaf and Dumb	......	1
CENTRAL CITY, COLO.		
Miners and Mechanics' Institute	......	3
CHAPEL HILL, N. C.		
University of North Carolina	1	......
CHAPPELL HILL, TEX.		
Soulé University	25	......
CHARLESTON, S. C.		
Charleston Library Society	2	4
Elliott Society of Natural History	11	18
South Carolina Historical Society	1	2
W. DeSaussure	1	......
CHARLESTON, N. H.		
Samuel Webber	1	......
CHARLESTON, W. VA.		
State Library	......	3
CHARLOTTE, N. C.		
Rev. Dr. Miller	......	1
CHARLOTTESVILLE, VA.		
University of Virginia	2	6
Prof. J. W. Mallett	......	2

Packages received by the Smithsonian Institution from Europe, &c.—Continued.

Address.	1872.	1873.
CHEYENNE, WYO.		
Territorial Library		3
CHICAGO, ILL.		
Chicago Academy of Science	126	82
Chicago Astronomical Society		1
Chicago Board of Trade	2	3
Chicago College of Pharmacy	1	2
Chicago Historical Society	1	2
Chicago Medical Times	9	7
Dearborn Observatory	14	10
Mayor of the city of Chicago		1
Public Library	1	10
State Natural History Society		1
Young Men's Association Library	2	
H. Babcock	1	
Prof. T. H. Safford	5	2
Dr. William Stimpson	3	
J. Q. A. Warren	1	
CINCINNATI, OHIO.		
Academy of Medicine		1
Astronomical Observatory	28	36
Astronomical Society	1	
College of Pharmacy		1
Dental Register	5	1
Historical and Philosophical Society		4
Mechanics' Institute	2	
Mercantile Library Association	2	3
Public Library	2	4
Western Academy of Natural Sciences	1	
Dr. F. Taft	1	1
CLIFTON, CANADA.		
United States Consulate		1
CLINTON, N. Y.		
Hamilton College		1
Litchfield Observatory of Hamilton College	7	3
Dr. C. H. F. Peters	4	9
COALBURGH, W. VA.		
W. H. Edwards	1	2
COLUMBIA, MO.		
Agricultural College	1	
Geological Survey of Missouri	3	11
University of Missouri	1	2
Dr. G. C. Swallow	3	4
COLUMBIA, PA.		
Prof. S. S. Haldeman		1
COLUMBIA, S. C.		
University of South Carolina	3	
South Carolina College		3
State Library		4
COLUMBUS, OHIO.		
Bureau of Statistics		1
Geological Survey of Ohio	2	4
Institution for the Deaf and Dumb	1	1
Ohio State Board of Agriculture	52	83
State Library	9	8
Prof. L. Lesquereux	6	6
Gov. E. F. Noyes		1
W. S. Sullivant	3	
CONCORD, N. H.		
New Hampshire Historical Society	5	5
CONCORD, N. H.—Continued.		
New Hampshire State Lunatic Asylum	2	
State Library		3
COUNCIL BLUFFS, IOWA.		
Institution for the Deaf and Dumb		1
CROW WING, MINN.		
Rev. Francis Pierz	1	
DANVILLE, KY.		
Institution for the Deaf and Dumb	1	1
DANVILLE, PA.		
Northern Hospital for the Insane	1	
DECORAH, IOWA.		
Norwegian Lutheran College	1	3
Prof. L. Larsen		4
DELAWARE OHIO.		
Wesleyan University		2
DELAVAN, WIS.		
Institution for the Deaf and Dumb	1	1
DENVER, COLO.		
Territorial Library		3
Gov. W. Gilpin	1	
DES MOINES, IOWA.		
Governor of the State of Iowa		1
State Library	4	7
DETROIT, MICH.		
Historical Society of Michigan		3
Michigan State Agricultural Society	11	14
Public Library		1
Review of Medicine and Pharmacy		2
Orlando B. Wheeler		1
DORCHESTER, MASS.		
Dr. Edward Jarvis	27	19
DOVER, DEL.		
State Library		3
DU LUTH, WIS.		
Scandinavian Library	1	
EASTON, PA.		
Lafayette College		1
Northwestern University		1
Prof. J. H. Coffin	2	2
Prof. T. C. Porter	2	1
ELMIRA, N. Y.		
Elmira Academy of Sciences	2	
EVANSTON, ILL.		
Dr. Henry Bannister		1
Prof. Oliver Marcy	1	1

Packages received by the Smithsonian Institution from Europe, &c.—Continued.

Address.	1872	1873.
FARIBAULT, MINN.		
Institution for the Deaf and Dumb	......	1
FARMINGTON, CONN.		
Edward Norton	3	2
FLINT, MICH.		
Institution for the Deaf and Dumb	1	1
FORT EDWARD, N. Y.		
Rev. L. G. Olmstead	2	......
FORT ERIE, CANADA.		
United States Consulate	......	1
FORT RANDALL, DAK.		
Dr. Elliot Coues	3	......
FOUNTAINDALE, ILL.		
M. S. Bebb	2	2
FRANKFORT, KY.		
Geological Survey of Kentucky	5	7
Public Library	......	1
State Library	.....	1
FREDERICK CITY, MD.		
Institution for the Deaf and Dumb	1	1
FREDERICTON, NEW BRUNSWICK.		
Legislative Library	......	1
University of New Brunswick	......	1
Prof. L. W. Bailey	1	......
Hon. W. Bryden Jack	2	......
FULTON, MO.		
Institution for the Deaf and Dumb	1	1
GALESBURGH, ILL.		
Lombard University	......	2
GALESVILLE, WIS.		
Galesville University	......	2
GAMBIER, OHIO.		
Kenyon College	2	2
GENEVA, N. Y.		
Prof. H. L. Smith	1	3
GEORGETOWN, D. C.		
Georgetown College	9	8
Dr. Arthur Schott	1	1
GEORGETOWN, PRINCE EDWARD ISLAND.		
United States Consulate	......	1
GLOUCESTER, N. J.		
Col. F. Austin	1	......
GREENCASTLE, IND.		
Indiana Asbury University	......	2
HALIFAX, NOVA SCOTIA.		
Nova Scotian Institute of Natural Sciences	7	14
United States Consulate	......	1
Lieutenant Bucknell	1	1
Lieut. Gen. Sir Hastings Doyle	......	1
T. Matthew Jones	......	1
HAMILTON, CANADA.		
United States Consulate	......	1
HAMILTON, N. Y.		
Madison University	1	3
HAMPDEN-SYDNEY, VA.		
Hampden-Sydney College	1	1
HANOVER, N. H.		
Dartmouth College	5	11
Observatory	1	......
Prof. C. H. Hitchcock	......	1
Prof. C. A. Young	......	4
HANTSPORT, NOVA SCOTIA.		
Rev. S. T. Rand	1	......
HARRISBURGH, PA.		
Medical Society of the State of Pennsylvania	......	2
State Agricultural Society	1	......
State Library	3	6
State Lunatic Hospital	3	......
HARTFORD, CONN.		
Connecticut Hospital for Insane	1	......
Historical Society of Connecticut	2	4
Institution for the Deaf and Dumb	1	1
State Agricultural Society	1	3
State Library	......	3
Trinity College	......	2
Young Men's Institute	1	4
HELENA, MONT.		
Historical Society of Montana	......	3
HILLSBOROUGH, N. C.		
Rev. M. A. Curtis	1	......
HOLLY GROVE, ARK.		
Literary Institute	......	3
HOT SPRINGS, ARK.		
Dr. Edw. Foreman	1	......
HOULTON, ME.		
Forest Club	......	3
HUDSON, OHIO.		
Western Reserve College	......	1
HYATTSVILLE, MD.		
State Agricultural College	1	......
INDIANAPOLIS, IND.		
Geological Survey of Indiana	7	6
Indiana Historical Society	2	4
Institute for Educating the Blind	4	......
Institution for the Deaf and Dumb	3	3
McIntyre Institution for Deaf Mutes	1	......

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Address.	1872.	1873.
INDIANAPOLIS, IND.—Continued.		
State Library	......	4
J H. Bradley	1	......
John W. Byrkit	1	......
E. F. Cox	18	7
J. MacIntyre	1	1
G. M. Levette	1	......
INMANSVILLE, WIS.		
Wisconsin Scandinavian Society	......	1
IOWA CITY, IOWA.		
Geological Survey of Iowa	2	1
Institution for Deaf and Dumb	1	......
Iowa State University	26	24
State Historical Society	......	3
Prof. G. Hinrichs	21	14
Prof. C. A. White	6	8
ITHACA, N. Y.		
Cornell College	......	5
Prof. F. E. Loomis	1	......
JACKSON, MISS.		
Institute for Deaf and Dumb	......	1
State Historical Society	......	3
State Library	......	1
JACKSONVILLE, FLA.		
Young Men's Christian Association	......	3
JACKSONVILLE, ILL.		
Institution for the Deaf and Dumb	1	1
State Hospital for the Insane	2	......
JAMAICA PLAINS, MASS.		
Bussey Institution	15	19
JANESVILLE, WIS.		
Wisconsin Institution for the Education of the Blind	......	2
JEFFERSON CITY, MO.		
Governor of the State of Missouri	......	1
Historical Society of Missouri	1	4
State Library	......	1
JERSEY CITY, N. J.		
S. Alossen	......	1
KANSAS CITY, MO.		
Young Men's Christian Association	......	3
KEYTESVILLE, MO.		
Charles Veatch	1	......
KINGSTON, CANADA.		
Botanical Society of Canada	1	4
King's College	......	1
Queen's College	......	1
KNOXVILLE, TENN.		
East Tennessee University	......	2
Institution for the Deaf and Dumb	......	6
Prof. F. H. Bradley	1	2
LANSING, MICH.		
State Library	......	2
LAWRENCE, KANS.		
Kansas Historical Society	......	3
University of Kansas	......	3
LEBANON, TENN.		
Cumberland University	1	1
Prof. James Safford	2	1
LEAVENWORTH, KANS.		
College of Pharmacy	......	1
Kansas Academy of Sciences	......	4
Mercantile Library Association	......	3
LEWISBURGH, PA.		
University	1	2
LEWISTON, ME.		
Androscoggin Natural History Society	......	3
LEXINGTON, KY.		
Eastern Lunatic Asylum	1	......
Kentucky University and State Agricultural Society	......	3
Transylvania University	1	1
LEXINGTON, VA.		
M. F. Maury	3	2
LIBERTY, VA.		
A. H. Curtiss	1	......
LINCOLN, NEBR.		
State Library	......	3
LITTLE ROCK, ARK.		
Governor of the State of Arkansas	......	1
Institution for the Deaf and Dumb	......	1
State Geologist	......	1
State Library	......	19
State University	......	2
LOCKPORT, N. Y.		
Col. E. Jewett	3	1
LONDON, CANADA.		
E. B. Reed	......	1
LONG VIEW, OHIO.		
Long View Asylum	1	......
LOUISVILLE, KY.		
College of Pharmacy	......	1
Kentucky Historical Society	......	3
Louisville and Richmond Medical Journal	1	3
Public Library of Kentucky	......	4
University of Louisville	2	3
LYNCHBURGH, VA.		
Medical Society of Virginia	1	......

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Address.	1872.	1873.
LYNN, MASS.		
Society of Natural History	......	1
MADISON, WIS.		
Agricultural Department	.....	1
State Historical Society of Wisconsin	3	9
Geological Survey of Wisconsin	1	......
Office of Emigration	......	1
State Library	......	4
University of Wisconsin	1	3
Wisconsin Academy of Sciences, Arts, and Letters	1	7
Wisconsin State Agricultural Society	......	55
MANCHESTER, N. H.		
City Library	......	2
MANITOBA, BRITISH AMERICA.		
Library of Saint John's College	......	1
MARQUETTE, MICH.		
Bishop Ignatius Maak	1	......
MIDDLETOWN, CONN.		
Wesleyan University	......	2
MILLEDGEVILLE, GA.		
State Library	......	4
University	1	1
MILWAUKEE, WIS.		
Natural History Society	5	3
W. Engelmann	1	......
Dr. I. A. Lapham	3	2
MOBILE, ALA.		
Charles Mohr	......	1
MONTGOMERY, ALA.		
State Library	......	4
MONTPELIER, VT.		
Historical Society of Vermont	1	1
State Library	2	6
MONTREAL, CANADA.		
Agricultural Society of Lower Canada	1	1
Geological Survey of Canada	4	11
McGill College	2	3
Montreal Observatory	1	......
Natural History Society	40	28
United States Consulate-General	......	2
Captain S. C. Bagg	1	......
Prof. E. Billings	5	......
H. Chaveau	......	1
P. P. Carpenter	3	......
Prof. J. W. Dawson	6	6
Lord Dufferin	1	......
T. Sterry Hunt	......	1
Sir W. E. Logan	1	7
Joseph McKay	1	......
David A. P. Watt	1	......
Dr. F. B. Wheeler	1	......
Prof. T. Whiteaves	......	1
MOUNT FOREST, (ONTARIO,) CANADA.		
William Wylie	1	......
NASHUA, N. H.		
Dr. B. K. Emerson	1	1
NASHVILLE, TENN.		
Geological Survey of Tennessee	4	6
State Library	2	4
Tennessee Historical Society	......	3
University	1	2
NEENAH, WIS.		
Scandinavian Library Association	1	1
NEWARK, N. J.		
Historical Society of New Jersey	......	1
NEW ALBANY, IND.		
Society of Natural History	1	......
NEW BEDFORD, MASS.		
J. H. Thomson	4	2
NEW BRUNSWICK, N. J.		
Geological Survey of New Jersey	14	5
Rutgers College	1	4
Prof. J. C. Smock	1	2
NEW COELN, WIS.		
Rev. T. A. Bruhm	1	......
NEW HAVEN, CONN.		
American Journal of Science and Art	49	48
American Oriental Society	17	17
Connecticut Academy of Arts and Sciences	86	84
Mercantile Library	1	......
Yale College	19	25
Prof. W. P. Blake	......	2
Prof. J. G. Brush	1	8
Prof. J. D. Dana	39	43
Prof. Daniel E. Eaton	......	3
Prof. E. Loomis	9	10
Prof. C. S. Lyman	1	......
Prof. O. C. Marsh	7	5
Prof. H. A. Newton	9	6
Prof. B. Silliman	16	15
Prof. Sidney Smith	2	6
Prof. A. E. Verrill	6	9
Prof. W. D. Whitney	6	8
Dr. T. D. Woolsey	1	......
Doctor Young	......	1
NEWPORT, VT.		
Orleans County Society of Natural Sciences	9	......
NEW ORLEANS, LA.		
Mayor of the city of New Orleans	......	1
Mechanics' Society Library	......	1
New Orleans Academy of Natural Sciences	53	54
University of Louisiana	......	1
Dr. J. G. Richardson	......	1
NEW YORK, N. Y.		
American Bible Society	......	1
American Bureau of Mines	......	1
American Christian Commission	8	......
American Chemist	1	2
American Druggists' Circular	......	1

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Address.	1872.	1873.
NEW YORK, N. Y.—Continued.		
American Geographical and Statistical Society	40	45
American Institute	25	31
American Institute of Architects	2	2
American Journal of Mining	2	......
American Microscopical Society	1	1
American Museum of Natural History	19	18
American Society of Civil Engineers	......	1
Anthropological Institute of New York	23	27
Apprentices' Library	......	1
Astor Library	7	17
Christian Inquirer Office	2	......
College of Pharmacy	......	1
Columbia College	2	1
Engineering and Mining Journal	1	......
Institution for the Deaf and Dumb	1	1
Institution for Improved Instruction of the Deaf and Dumb	......	1
Journal of Psychological Medicine and Anthropology	3	2
Liberal Christian		6
Lyceum of Natural History	107	104
Mayor of the city of New York	1	2
Medical Gazette	1	......
Medical Journal	1	3
Mercantile Library Association	3	9
Metropolitan Board of Health	3	3
National Board of Underwriters	1	......
New York Academy of Medicine	6	5
New York City Lunatic Asylum	2	......
New York Historical Society	5	6
New York Hungarian Society	......	1
New York Medico-Historical Society	......	3
New York Prison Association	1	......
Numismatic and Archæological Society	1	......
Office of the Sanitarian	......	1
School of Mines	5	7
Scientific American	1	......
Society for the Protection of Animals	......	1
State Commissioner of Public Charities	1	......
United States Sanitary Commission	2	11
University of New York	5	8
William Angermann	1	......
Prof. F. A. P. Barnard	1	3
Dr. Fordyce Barker	1	......
A. S. Bickmore	1	......
Thomas Bland	2	......
Dr. H. C. Bolton	4	......
Rev. Nathan Brown	1	......
Prof. C. F. Chandler	3	7
Daniel Draper	......	1
Dr. H. Draper	3	7
Prof. T. Egleston	1	2
Anton Eilns	1	......
Capt. John Ericsson	2	1
David Dudley Field	......	1
George Folsom	3	2
H. Flugel	1	......
Henry Grinnell	2	4
W. A. Haines	......	1
Dr. Elisha Harris	1	......
William B. Hodgson	1	2
Prof. Charles A. Joy	1	1
Dr. James P. Kimball	......	2
Kirschner & Co	......	1
Dr. H. Knapp	......	1
George N. Lawrence	2	......
Mrs. C. A. Lombard	......	1
Dr. J. S. Newberry	7	9
Dr. J. C. Nott	3	1
Prof. W. G. Peck	1	......
Temple Prime	1	2
Alfred Pell, jr	2	......
Baron Ostensacken	1	......
Dr. A. E. M. Purdy	......	2
Prof. Charles Rau	1	1
Dr. R. W. Raymond	2	1
Dr. J. Rösing	1	......
R. P. Rothwell	......	1
Samuel B. Ruggles	1	1
L. M. Rutherford	1	3
Julius Schlüter	1	1
H. M. Scheiffelin	2	......
L. W. Schmidt	1	......
Charles Stephani	1	......
E. G. Squier	4	3
Dr. John Torrey	5	......
Western & Co., Journal of Mining	2	4
Gen. Prosper Wetmore	1	......
Dr. E. C. Wines	......	2
Charles F. Wingate	......	1
NILES, CAL.		
Lorenzo G. Yates	1	1
NORTHAMPTON, MASS.		
Clarke Institution for Deaf Mutes	2	2
State Lunatic Hospital	1	1
NORWICH, CONN.		
Hon. David A. Wells	1	1
OAKLAND, CAL.		
Institution for the Deaf and Dumb	......	1
OLATHE, KANS.		
Institution for the Deaf and Dumb	......	1
OLYMPIA, WASH.		
Territorial Library	......	4
OMAHA, NEBR.		
Institute for the Deaf and Dumb	......	1
Nebraska Historical Society	......	3
ORONO, ME.		
Maine State College of Agriculture	1	......
OTTAWA, CANADA.		
United States Consulate	......	1
Library of Parliament	......	6
Alpheus Todd	......	1
OTTAWA, ILL.		
Ottawa Academy of Natural Sciences	3	7
OWEN SOUND, CANADA.		
Mrs. Jessie D. Roy	......	2
OXFORD, MISS.		
University of Mississippi	......	4
Eugene W. Hilgard	......	2
OXFORD, OHIO.		
Miami University	......	2
PENN YAN, N. Y.		
Dr. S. H. Wright	......	1

Packages received by the Smithsonian Institution from Europe, &c.—Continued.

Address.	1872.	1873.
PEORIA, ILL.		
Mercantile Library Association	......	5
Dr. F. Brendel	1	1
PHILADELPHIA, PA.		
Academy of Natural Sciences	203	193
American Entomological Society	17	8
American Journal of Conchology	4	3
American Pharmaceutical Association	31	27
American Philosophical Society	131	132
Central High School	......	3
Central High-School Observatory	......	1
College of Pharmacy	......	1
College of Physicians	......	1
Dental Cosmos	3	1
Dental Laboratory	3	......
Dental Times	3	1
Franklin Institute	30	30
Girard College	4	1
Historical Society of Pennsylvania	6	11
Library Company	3	5
Mayor of the city of Philadelphia	......	1
Medico-Chirurgical Review	3	2
Medical and Surgical Reporter	2	......
Medical Times	6	10
Mercantile Library	......	1
Numismatic Society	2	......
Pennsylvania Institution for the Blind	1	......
Pennsylvania Institution for the Deaf and Dumb	2	3
Philadelphia Society for Promoting Agriculture	......	1
Polytechnic College	1	1
Public Schools	......	2
Society for the Protection of Animals	......	1
University of Pennsylvania	2	1
Wagner Free Institute of Science	16	15
Rev. Dr. E. R. Beadle	3	4
Lorin Blodget	1	......
W. Brotherhead	1	......
Dr. S. W. Butler	1	1
H. C. Carey	2	1
Pliny E. Chase	1	......
George W. Childs	1	......
Prof. T. A. Conrad	1	3
Prof. E. D. Cope	5	3
E. T. Cresson	1	1
Israel Dille	......	2
H. Drayton	1	......
Prof W. M. Gabb	3	2
Dr. Genth	......	2
H. C. Lea	......	1
Dr. Isaac Lea	12	16
Dr. John L. Le Conte	7	10
Dr. Joseph Leidy	13	16
J. P. Lesley	1	1
J. L. Lund	......	1
B. S. Lyman	......	2
Dr. J. Aitken Meigs	4	1
Professor Mitchell	......	1
Franklin Peale	1	......
Henry Phillips	1	......
Dr. F. G. Richardson	1	3
Benjamin Smith	2	......
George W. Tryon, jr	2	6
W. S. Vaux	1	......
Prof. W. Wagner	2	......
Dr. Horatio C. Wood, jr	4	2
PICTOU, NOVA SCOTIA.		
United States Consulate	......	1
PINE LAKE, WIS.		
Wisconsin Scandinavian Society	......	1
PITTSBURGH, PA.		
Pittsburgh Day School for the Deaf and Dumb	......	1
POMARIA, S. C.		
William Summer	1	......
PORTLAND, ME.		
Portland Society of Natural History	43	65
PORT HOPE, CANADA.		
Rev. C. J. S. Bethune	1	......
PORT SARNIA, CANADA.		
United States Consulate	......	1
PORT TOWNSEND, WASH.		
James G. Swan	1	......
POUGHKEEPSIE, N. Y.		
Vassar College	3	2
Miss Maria Mitchell	1	......
PRESCOTT, ARIZONA.		
Territorial Library	......	3
PRESCOTT, CANADA.		
United States Consulate	......	1
PRINCETON, N. J.		
Agricultural Society	1	......
College of New Jersey	5	17
Prof. S. Alexander	......	1
A. D. Brown	1	......
Prof. A. Guyot	......	6
Prof. C. Hodge	3	1
PROVIDENCE, R. I.		
Athenæum	......	1
Brown University	6	4
Rhode Island Historical Society	2	7
State Library	......	3
John R. Bartlett	2	......
S. T. Olney	1	......
Dr. E. Snow	5	11
QUAKERTOWN, PA.		
Dr. J. S. Moyer	......	1
QUEBEC, CANADA.		
Laval University	......	1
Literary and Historical Society	......	26
United States Consulate	......	1
RALEIGH, N. C.		
State Library	......	4
Institution for the Deaf and Dumb	1	1
Prof. W. C. Kerr	......	1
RICHMOND, VA.		
Medical Society of Virginia	......	3
State Library	3	6
Virginia Historical Society	1	4
Thomas H. Wynne	1	......

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Address.	1872.	1873.
ROCHESTER, N. Y.		
University	......	2
Prof. Henry A. Ward	1	1
ROMNEY, W. VA.		
Institution for the Deaf and Dumb	......	1
RUTLAND, VT.		
Vermont Pharmaceutical Association	......	1
SACRAMENTO, CAL.		
Geological Survey of California	5	......
State Agricultural Society	1	......
State Library	......	4
SAINT ANTHONY, MINN.		
University	......	1
Dr. A. Robertson	2	......
SAINT AUGUSTINE, FLA.		
Historical Society of Florida	......	3
SAINT JOHN, CANADA.		
United States Consulate	......	1
SAINT JOHN, NEW BRUNSWICK.		
Mechanics' Institute	......	1
Natural History Society	2	9
United States Consulate	......	1
G. F. Matthews	......	16
Gilbert Murdock	......	1
Prof. Alleyne Nicholson	......	1
SAINT JOHN'S, NEWFOUNDLAND.		
United States Consulate	......	1
SAINT LOUIS, MO.		
College of Pharmacy	......	1
Institution for the Deaf and Dumb	1	1
Mercantile Library	......	4
Missouri Dental Journal	3	1
Public School Library	1	1
Saint Louis Academy of Sciences	120	91
University of Saint Louis	4	5
Dr. Louis Bauer	......	1
Ernst Von Engelbrodt	......	1
Dr. G. Engelmann	4	11
N. Holmes	1	1
Dr. M. L. Linton	1	......
Dr. H. A. Prout	1	1
Prof. R. Pumpelly	......	1
C. V. Riley	1	1
Maurice Schuster	1	1
Doctor Wisligenus	......	1
SAINT PAUL, MINN.		
Academy of Natural Science	......	3
Chamber of Commerce	1	......
Institution for Deaf and Dumb	1	......
Minnesota Historical Society	14	10
State Library	......	3
J. R. Kloos	......	2
SALEM, MASS.		
American Association for Advancement of Science	37	40
American Naturalist	1	......
Essex Institute, Salem	103	90
Peabody Academy of Science	77	57
SALEM, MASS.—Continued.		
E. S. Morse	1	......
Dr. A. S. Packard	19	12
F. W. Putnam	......	1
SALEM, OREG.		
Institution for the Deaf and Dumb	......	1
State Library	......	3
SALT LAKE CITY, UTAH.		
Territorial Library	......	3
SAN FRANCISCO, CAL.		
California Academy of Natural Sciences	17	116
Institution for Deaf and Dumb	1	......
Mayor of the city of San Francisco	......	1
Mercantile Library Association	1	1
Pharmaceutical Society	......	1
Society for the Protection of Animals	......	1
Henry A. Bolander	1	2
Dr. J. G. Cooper	......	1
Doctor Johnson	1	......
R. E. C. Stearns	1	7
Frederick Whymper	......	2
F. Benton	2	......
H. G. Bloomer	1	......
SANTA FÉ, N. MEX.		
Historical Society of New Mexico	......	3
Territorial Library	......	3
SAVANNAH, GA.		
Historical Society of Georgia	1	4
SCHENECTADY, N. Y.		
Jonathan Brown	......	1
Union College	1	......
SEAVILLE, N. J.		
E. C. Cole	1	......
SING SING, N. Y.		
Dr. G. J. Fisher	1	......
SOUTH BETHLEHEM, PA.		
Lehigh University	......	2
SPRINGFIELD, ILL.		
Illinois State Agricultural Society	4	1
State Library	......	3
Prof. A. H. Worthen	8	9
STAUNTON, VA.		
Institution for the Deaf and Dumb	1	1
STOCKTON, CAL.		
State Lunatic Hospital	1	......
SYRACUSE, N. Y.		
Prof. A. Winchell	......	9
TALLADEGA, ALA.		
Institution for the Deaf and Dumb	......	1

Packages received by the Smithsonian Institution from Europe, &c.—Continued.

Address.	1872.	1873.
TARRYTOWN, N. Y.		
General J. C. Frémont	4	4
TAUNTON, MASS.		
State Lunatic Hospital	1	......
TOPEKA, KANS.		
Kansas Natural History Society	......	3
State Library	......	1
TORONTO, CANADA.		
Canadian Institute	16	14
Chemists' Association	......	1
Literary and Philosophical Society	1	2
Observatory	7	5
Pharmaceutical Society	......	1
Trinity College	......	1
United States Consulate	......	1
University of Canada	1	1
Dr. A. Milton Ross	2	3
Rev. Daniel Wilson	1	......
TRENTON, N. J.		
State Library	......	3
State Lunatic Asylum	1	......
URBANA, OHIO.		
Urbana University	......	1
UTICA, N. Y.		
American Journal of Insanity	6	1
State Lunatic Asylum	3	......
VANDALIA, ILL.		
Historical and Archæological Society	......	1
VICTORIA, VANCOUVER'S ISLAND.		
United States Consulate	......	1
WASHINGTON, D. C.		
American Annals of the Deaf and Dumb	......	1
Board of Indian Commissioners	2	2
Bureau of Navigation	1	5
Bureau of Statistics	10	9
Census Bureau	5	5
Clinico-Pathological Society	......	1
Columbian Institution for the Deaf and Dumb	5	1
Department of Agriculture	156	140
Department of Education	......	1
Engineer Department	3	3
General Land-Office	6	2
Governor of the District	1	......
Howard University	......	1
Hydrographic Office	4	6
Library of Congress	19	15
Light-House Board	1	1
Medical Society of the District of Columbia	2	4
National Academy of Science	58	48
National Deaf Mute College	......	2
Nautical Almanac Office	6	7
Navy Department	1	1
Ordnance Bureau	1	5
Pharmaceutical Association	......	1
President of the United States	3	1
Public Schools	4	1
Secretary of the Navy	......	1
Signal-Office	2	14
State Department	2	3
WASHINGTON, D. C.—Continued.		
Surgeon-General's Office	153	122
Treasury Department	1	1
United States Coast Survey	42	54
United States Geological Survey	......	5
United States Naval Observatory	90	91
Patent Office	189	161
War Department	3	4
Dr. Cleveland Abbe	2	8
A. W. Angerer	......	1
Prof. A. Ashley	......	2
Prof. S. F. Baird	45	37
Dr. H. M. Bannister	1	......
Blacque Bey	1	......
J. C. Bille	1	......
Admiral Boggs	1	......
Dr. Elliott Coues	......	5
Adolf Cluss	2	......
Vincent Colyer	1	......
Prof. J. H. C. Coffin	3	......
Dr. Edward Curtis	......	1
W. H. Dall	1	......
Maurice Delfosse	1	......
Israel Dille	......	2
Capt. Du Pont	......	1
T. R. Dodge	1	......
Prof. J. R. Eastman	......	2
E. B. Elliott	1	......
General W. H. Emory	1	......
E. A. Fay	1	......
William Ferrel	1	......
Señor L. A. de Padua Fleury	1	......
Don Antonio Flores	1	......
Don Manuel Freyre	1	......
Don Manuel R. Garcia	1	......
Hon. J. A. Garfield	1	......
Señor Don Joaquin Godoy	1	......
B. S. Hedrick	1	......
G. W. Hills	1	......
Prof. C. H. Hitchcock	1	......
John Hitz	1	......
Hon. H. R. Hurlbut	1	......
Baron Charles Lederer	1	......
Chevalier de Lansay Lobo	1	......
Com. Stephen B. Luce	1	......
Prof. G. A. Matile	2	......
Hon. H. E. Paine	1	......
Dr. Edw. Palmer	1	......
Capt. Foxhall A. Parker	1	......
Dr. C. C. Parry	3	......
Hon. R. C. Parsons	1	......
Prof. B. Peirce	10	......
Don Antonio Perez	1	......
Count Luigi Porti	1	......
Count L. F. de Pourtales	6	......
Com. W. Reynolds	1	......
Robert Ridgway	2	......
Prof. T. Gill	4	2
Prof. A. Hall	1	1
Prof. W. Harkness	......	1
Dr. F. V. Hayden	27	25
Prof. J. Henry	35	28
Prof. J. E. Hilgard	2	3
Prof. E. S. Holden	......	1
J. C. G. Kennedy	5	2
Miss Emma Marwedel	......	1
F. B. Meek	21	15
Maj. Gen. M. C. Meigs	1	1
Brig. Gen. A. J. Myer	2	6
Prof. J. E. Nourse	......	1
Prof. S. Newcomb	5	6
Hon. Peter Parker	2	2
T. Pœsche	5	3
Rear-Admiral B. F. Sands	3	5
Joseph Saxton	1	......
George C. Schaeffer	1	......
Hon. H. von Schlatzel	1	......
Charles A. Schott	2	2
W. H. Seaman	1	1
Hon. John Sherman	1	......

Packages received by the Smithsonian Institution from Europe, &c.—Continued.

Address.	1872.	1873.	Address.	1872.	1873.
WASHINGTON, D. C.—Continued.			WILLIAMSBURGH, VA.		
Olaf Stenerson	1	......	Eastern Lunatic Asylum	......	1
James Stephenson	1	......	WILMINGTON, DEL.		
Osmond Stone	......	1	Agricultural Society	......	2
Hon. Charles Sumner	......	1	WINDSOR, CANADA.		
Prof. Cyrus Thomas	4	......	United States Consulate	......	1
Sir Edward Thornton	1	......	WINDSOR, NOVA SCOTIA.		
Dr. J. M. Toner	1	......	Library of King's College	......	1
Henry Ulke	2	......	H. G. Hind	......	2
Hon. W. H. Upson	1	......	WORCESTER, MASS.		
Maj. Gen. G. K. Warren	......	1	American Antiquarian Society	10	15
Hon. H. Westenberg	1	......	State Lunatic Hospital	1	......
Dr. J. J. Woodward	......	5	WYANDOTTE, KANS.		
Clarence B. Young	6	1	Wyandotte Library Association	......	3
WATERVILLE, ME.			YONKERS, N. Y.		
Waterville College	2	1	H. M. Schieffelen	......	1
WATERVILLE, OHIO.					
Otterbein University	......	1			
WESTCHESTER, PA.					
W. D. Hartmann	1	......			
WESTFORD, CONN.					
Dr. C. C. Parry	......	1			

RECAPITULATION.

Packages received, &c.	1872.	1873.
Total addresses of institutions	300	463
Total addresses of individuals	287	226
	587	689
Total number of parcels to institutions	3, 694	3, 876
Total number of parcels to individuals	941	906
	4, 635	4, 782

CLASSIFIED RECORD OF MONTHLY METEOROLOGICAL REPORTS PRESERVED IN THE SMITHSONIAN INSTITUTION.

Name of station.	Period.	Name of observer.
NORTH AMERICA.		
BRITISH AMERICA.		
Abitibi Post	1868–1869	James Lockhart.
Fort Anderson Fort George	1863	R. Macfarlane.
Fort Liard	1860	R. Kennicott.
Fort Nascopee	1863–1865	H. Connolly.
Fort Norman	1862–1863	Andrew Flett.
Fort Rae	1859–1860	Lawrence Clark, jr.
Fort Rae, Great Slave Lake	1861–1864	Mrs. Lawrence Clark, jr.
Fort Simpson, Great Slave Lake	1848–1861	B. R. Ross.
Kenoqumissee	1861–1863	Thomas Richards.
Little Whale River	1862	Walter Dickson.
Moose Factory	1857–1862	J. Mackenzie.
Moose Factory to Lake Superior	1862	Colin Rankin.
Red River Settlement	1857–1861	Donald Gunn.
Rigolet, Labrador	1859–1860	H. Connelly.
Victoria, Vancouver's Island.	1863–1864	Dr. David Walker.
Winnipeg	1869–1873	James Stewart.
CANADA.		
New Brunswick.		
St. John's	1859–1873	Gilbert Murdock.
Nova Scotia.		
Halifax	1859–1861	Royal Engineers.
	1863–1865	Col. W. J. Myers.
	1854	Board of Trade.
	1859	R. J. Nelson.
Pictou	1843–1855	Henry Poole.
Windsor	1857–1862	King's College.
Wolfville	1867–1873	D. F. Higgins.
	1854	Acadia College.
	1858–1859	C. F. Hart.
	1855–1858	Prof. A. P. S. Stuart.
Ontario.		
Clifton	1867–1873	W. Martin Jones.
Hamilton	1857–1862	Dr. W. Craigie.
Kingston.	1859–1860	J. Williamson.
Michipicoton	1860–1866	Colin Rankin.
Mount Forest	1872–1873	W. Wylie.
Niagara	1861–1863	H. Phillips.
Toronto	1856–1868	Magnetic Observatory.
	1849, 1851–1852	Capt. J. H. Lefreoy.
Quebec.		
Montreal	1855–1863	Dr. A. Hall.
Port Neuf	1868	Observations published in Naturaliste Canadien.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
St. Martin	1852–1862	Dr. Charles Smallwood.
Stanbridge	1857–1865	J. C. Baker.
	1868–1873	A. H. Gilmour.
Stratford	1861–1862	C. J. Macgregor.
NEWFOUNDLAND.		
Harbor Grace	1871–1872	Henry A. Clift.
	1872–1873	Archibald Munn.
St. John's	1857–1864	John Delany, jr., E. M. J. Delany.
	1871–1873	John Delany.
	1849	H. B. M. military post.
	1868–1869	Rev. R. C. Caswell.
UNITED STATES.		
Alabama.		
Ashville	1857	Thomas M. Barker.
Auburn	1854–1858	Prof. John Darby.
Benton	1849–1851	Dr. Charles F. Percival.
Bluff Springs	1872	W. W. Wilson.
Boligee	1860	Col. Horace Harding.
Bon Secours	1866–1867	W. J. Vankirk.
Cahaba	1859	Dr. Matthew Troy.
Carlowville	1856–1860, 1867–1873	Dr. H. L. Alison.
Columbiana	1873	W. B. Sommerville.
Erie	1849	Dr. Samuel K. Jennings.
	1851–1852	Dr. T. C. Osborne.
Eutaw	1851–1852	A. Winchell.
Fish River	1868–1871	W. J. Vankirk.
Greensborough	1856–1862	Robert B. Waller.
	1868	N. T. Lupton.
Havana	1853, 1859–1861, 1866–1873.	Prof. H. Tutwiler.
Havana, six miles east of	1868–1871	Dr. S. K. Jennings.
Huntsville	1871–1873	Dr. E. L. Antony.
Livingston	1859–1860	Rev. S. U. Smith.
McMaths, Post-Office	1854	R. T. Meriwether.
Marion	1873	D. H. Sumner.
Mobile	1849	Dr. S. B. North.
Mobile	1859	Rev. J. J. Nicholson.
	1869–1870	Lewis B. Taylor.
Monroeville	1849, 1851–1855	S. J. Cumming.
Montgomery	1859–1861	Rev. J. A. Shepherd.
	1859–1860	W. L. Foster.
Moulton	1866	Andrew J. Harris.
	1866–1873	Thomas J. Peters.
	1861	Prof. J. Shackelford.
	1859	Ashley D. Hunt.
Opelika	1867–1871	J. H. Shields.
Orville	1859–1860	Dr. S. K. Jennings.
	1860	T. A. Huston and J. A. Coleman
Prairie Bluff	1867	William Henderson.
	1867	R. M. Reynolds.
Selma	1858–1859	Dr. S. K. Jennings.
	1873	C. Cadle, jr.
	1870–1871	Dr. C. F. Fahs and Miss Deans.
	1872	Dr. H. S. Hudson.
Spring Hill	1866	A. Cornette.
Troy	1872–1873	D. P. Hurley.
Tuscaloosa	1853–1854	Prof. M. Tuomey.
	1854–1855	George Benagh.
Union Springs	1868	J. L. Moultrie.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Uniontown	1859–1860	Rev. R. A. Cobbs.
Wetokaville	1849, 1851–1854	Benjamin F. Holly.
Alaska.		
Fort Youkon	1861	R. Kennicott.
Nulato	1866–1867	W. H. Dall.
Saint Paul's Island	1870–1871	Charles Bryant.
Sitka	1867–1868	Dr. Alexander H. Hoff.
	1868–1870	Charles Bryant.
Saint Michael's	1865–1866	H. M. Bannister.
	1865–1866	J. W. Bean.
Unalakleet	1866–1867	F. Westdahl.
Arizona.		
Fort Whipple	1865	Dr. E. Coues.
Arkansas.		
Arkadelphia	1859	Dennis Barlow.
	1860	Female College.
Bentonville	1859–1861	Paul Graham.
Brownsville	1859–1860	B. F. Coulter.
Buckhorn	1859	Armistead Younger.
Clarksville	1871–1872	E. Greene.
Doaksville	1860	Miss S. McBeth.
Fayetteville	1870–1872	Charles L. McClung.
Forest City	1872–1873	William F. Wellborn.
Fort Smith	1866–1867	Rev. Francis Springer.
Gainesville	1859	James T. Davies.
Green Grove	1860	Dr. Robert Burris.
Helena	1865–1873	O. F. Russell.
Jacksonport	1859–1860	Dr. G. A. Martin.
Little Rock	1849	Philip L. Anthony.
Micco	1860	Rev. H. F. Buckner.
Mineral Springs	1870–1873	Harmon Bishop.
	1873	Prof. D. C. Cowling.
	1872	J. G. P. McLenden.
Mountain Home	1861	J. S. Howard.
Mount Ida	1872–1873	Granville Whittington.
Perryville	1859–1861	W. H. Blackwell.
	1856	H. F. Hardy.
Pocahontas	1871–1872	Joseph P. Martin.
Spring Hill	1859	P. F. Finley.
	1859–1860	J. Reynolds.
	1860	P. F. Finley and J. Reynolds.
Waldron	1859–1860	George W. Featherstone.
Washington	1861	Dr. Alexander P. Moore.
	1849–1861	Dr. N. D. Smith.
	1871	Charles White.
	1872	J. E. Borden.
Yellville	1859–1860	J. W. Weast.
	1859–1860	W. B. Flippin.
California.		
Auburn	1859–1860	Robert Gordon.
Cahta	1869–1872	Doctor Thornton.
Chico	1869–1872	Dr. W. Fitch Cheney.
Clayton	1870	Charles L. McClung.
Columbia	1857–1860	Dr. Silas Earle.
Crescent City	1859–1860	Robert B. Randall.
Downieville	1860	Dr. T. R. Kibbe.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
El Monte	1872–1873	George H. Peck.
Folsom	1861	Rev. S. V. Blakeslee.
Fort Yuma	1867	
Honcut	1859	James Slaven.
	1860	J. Slaven and Mrs. E. S. Dunkum.
	1861–1863	Mrs. E. S. Dunkum.
Indian Valley	1870–1871	Miss M. E. Pulsifer.
	1872–1873	Mrs. M. E. P. Ames.
La Grange	1873	Joseph Domenici.
Mare Island	1868–1873	United States naval hospital.
Marsh's Ranche	1867–1868	Francis M. Rogers.
Martinez	1860	Edwin Howe.
Marysville	1857-1859, 1861-1863,	W. C. Belcher.
Meadow Valley	1860–1862	James H. Whitlock.
	1864	Dr. Colbert A. Canfield.
	1863–1868	M. D. Smith.
Mendocino City	1872	Doctor Thornton.
Mokelumne Hill	1859–1861	Wesley K. Boucher.
Monterey	1859–1860, 1864–1872	Dr. Colbert A. Canfield.
Murphy's	1868–1869	Ephraim Cutting.
National City	1872–1873	J. M. Asher.
Paradise City	1869	W. A. Wright.
Presidio of San Francisco	1862	Dr. W. W. Hays.
	1863–1864	D. F. Parkinson.
	1852–1861	Post surgeon.
Sacramento	1854	Dr. F. W. Hatch.
	1855	Drs. F. W. Hatch and T. M. Logan.
	1849–1868	Dr. T. M. Logan.
	1863	Charles Craft.
Salinas City	1872–1873	Dr. E. K. Abbott.
San Diego	1871–1872	Dr. G. W. Barnes.
San Francisco	1856–1863, 1865–1868	Dr. W. O. Ayres.
	1854–1855	Dr. H. Gibbons.
Santa Barbara	1864	Dr. W. W. Hays.
Santa Clara	1859–1861	Prof. O. S. Frombes.
	1859	Lewis A. Gould.
Santa Cruz	1873	A. L. Taylor.
Santa Rosa	1873	Prof. W. B. Hardy.
Spanish Ranche	1862–1863	M. D. Smith.
	1864–1866	Mrs. M. D. Smith.
Stockton	1855–1856	Dr. Robert K. Ried.
	1867	Walter M. Trivett.
Stony Point	1869	Doctor Thornton.
Union Ranche	1858	W. L. Dunkum.
Vacaville	1869–1870	Prof. J. C. Simmons.
Visalia	1870–1871	J. W. Blake.
Watsonville	1869–1872	Dr. A. J. Compton.
Colorado.		
Canyon City	1869	Thomas Macon.
Central City	1860–1861	W. D. McLain.
Colorado City	1871	A. M. Merriam.
Colorado Springs	1871–1872	E. S. Nettleton.
	1872–1873	E. S. Nettleton and E. Cropley.
Denver City	1859	D. C. Collier.
	1869–1873	W. N. Byers and S. Y. Sopris.
Fort Collins	1872–1873	R. Q. Tenney.
Fountain	1866–1867	Arthur M. Merriam.
	1871–1873	Clayton J. Croft.
Golden City	1867	E. L. Berthoud.
	1871–1873	George W. Davies.
Las Animas	1873	R. F. Long.
Montgomery	1863–1865	James Luttrell.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Mountain City	1860-1862	Dr. William T. Ellis.
Pueblo	1873	E. S. Nettleton.
Connecticut.		
Brookfield	1868-1870	Sanford W. Roe.
Canton	1861-1863	Jarvis Case.
Colebrook	1860-1873	Miss C. Rockwell.
Columbia	1856-1873	W. G. Yeomans.
East Windsor Hill	1852	P. A. Chadbourne.
Georgetown	1855-1857	Aaron B. Hull.
Groton	1866-1868	Rev. E. Dewhurst.
Hartford	1849-1851	Charles H. Hoadley.
Middletown	1854-1858, 1859-1868	Prof. J. Johnston.
	1849-1852	Prof. A. W. Smith.
	1868-1873	Prof. J. Johnston and H. D. A. Ward.
New Haven	1859	H. G. Dubois, jr.
	1862-1864	D. C. Leavenworth.
	1849-1851	Prof. E. Cutler.
New London	1849-1851, 1852-1858	Rev. Tryon Edwards.
North Colebrook	1849-1851	M. H. Cobb.
North Greenwich	1870-1873	Rev. W. P. Alcott.
Norwich	1855-1858	N. Scholfield.
Plymouth	1862-1864	Dwight W. Learned.
Pomfret	1853-1869	Rev. Daniel Hunt.
Salisbury	1849-1851, 1853-1854	Dr. Ovid Plumb.
Saybrook	1853-1861	James Rankin.
	1872	Aug. Barnes.
Southington	1870-1873	Luman Andrews.
Wallingford	1856-1862	Benjamin F. Harrison.
Waterbury	1867-1869	Rev. R. G. Williams.
West Cornwall	1854	T. S. Gold.
Windsor	1851	R. H. Phelps.
Dakota.		
Bon Homme	1872	H. C. Greene.
Cheyenne	1872	A. R. Baylis.
Fargo	1872	Henry Ambrose.
Fort Union	1857-1858	F. G. Riter.
Greenwood	1859-1861	Freeman Norvell.
Ponka Agency	1871	Rev. J. Owen Dorsey.
Yankton	1865	M. K. Armstrong.
	1862	G. D. Hill, G. W. Lawson, H. G. Williams.
	1863	H. G. Williams.
Delaware.		
Delaware City	1866-1867	L. Vankekle.
Dover	1854	J. P. Walker.
	1870-1873	J. H. Bateman.
Georgetown	1859	Dr. D. W. Mauld.
Lewes	1849	John Burton.
Milford	1857-1858	R. A. Martin.
	1869-1870	Mrs. A. C. Whittier.
	1870-1871	Mrs. W. R. Phillips.
	1871-1873	R. H. Gilman.
Newark	1849	Prof. W. A. Norton.
	1852	Prof. E. D Porter.
	1854	Prof. W. A. Crawford.
	1855	Prof. W. A. Crawford, R. A. Martin.
	1856	Prof. W. A. Crawford, R. A. Martin, T. J. Craven.
	1857	Thomas J. Craven, Mrs. E. D. Porter.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Newark	1858	Mrs. E. D. Porter.
	1856	Robert Crawford.
Wilmington	1863–1865	Urban D. Hedges.
District of Columbia.		
Georgetown	1860–1863	Rev. C. B. McKee.
Washington	1852–1860, 1864–1867	United States Naval Observatory.
	1857–1858	J. Wiessner.
	1854–1874	Smithsonian Institution.
Florida.		
Alligator	1857–1858	Edward R. Ives.
Atsena Otie	1859–1861	Aug. Steele.
Belair	1857–1858	Benjamin F. Whitney.
Bicolata	1871–1872	Charles F. Powell.
Biscayne	1870	W. H. Hunt.
	1872–1873	E. T. Sturtevant.
Cedar Keys	1851–1858	Aug. Steele.
Chattahoochie Arsenal	1869–1870	M. Martin.
Chestnut Hill	1851	John Newton.
Daytona	1870–1873	S. N. Chamberlin.
Fernandina	1867	Henry M. Corey.
Fort George	1872–1873	John F. Rollins.
Gainesville	1855–1861	James B. Bailey.
Gordon	1866	Dr. P. C. Garvin.
	1866–1868	H. B. Scott.
Green Cove Spring	1868	G. A. Boardman.
Hibernia	1857–1858	F. L. Bachelder.
Jacksonville	18531–860, 1866–1872	Dr. A. S. Baldwin.
Key West, (Salt Pond)	1854–1864	W. C. Dennis.
(Mag. obs.)	1860–1861	George D. Allen.
	1861–1862	G. F. Ferguson and J. G. Oltmans.
Knox Hill	1852–1853	John Newton.
Lake City	1859–1860, 1866–1869	Edward R. Ives.
	1867	Galen M. Fisher.
	1868	Rev. W. W. Keep.
Manatee	1869–1870	B. A. Coachman.
Mayport	1873	W. F. Keeler.
Micanopy	1858–1860	Dr. James B. Bean.
Newport	1870–1873	Rev. Charles Beecher.
New Smyrna	1873	George J. Alden.
	1871–1872	Edm. K. Lowd.
Ocala	1868–1872	Edward Barker.
Orange Grove	1870	W. J. Clarke.
Orange Hills	1854	John Newton.
Pensacola	1849, 1857–1860	United States navy-yard.
	1851–1854	J. Pearson.
	1855	J. Pearson and Jos. Fry.
	1856	Jos. Fry.
	1857	Jos. Fry and J. W. Hester.
	1858	Lieut. J. W. Hester.
Pilatka	1869–1872	Gen. George D. Robinson.
	1869	W. M. L. Fiske.
Port Orange	1867–1870	Dr. J. M. Hawks.
Springfield	1872–1873	Edward Barker.
Saint Augustine	1849	Dr. John E. Peck.
	1856–1860	Dr. P. B. Mauran.
	1870–1871	George W. Atwood.
Tallahassee	1859–1861	Benjamin F. Whitner.
	1852	W. S. Bogert.
	1859–1860	Lardner Gibbon.
	1872	Truman S. Betts.
Tampa	1871–1873	W. F. White.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Uchee Anna	1849	John Newton.
Warrington	1859–1860	Thayer Abert.
Welborn	1871–1873	George R. Thralls.
White Springs	1870	R. W. Adams.
Georgia.		
Athens	1857–1859	Prof. John D. Easter.
Atlanta	1859–1860	J. G. Westmoreland.
	1865–1873	Fred. Deckner and son.
	1873	G. W. Walker.
Augusta	1854–1857	William Haines.
	1854	William Schley.
	1858–1860	Dr. W. H. Doughty.
Berne	1870–1873	H. L. Hillyer.
Boston	1865–1868	Rev. W. Blewitt.
Cabaniss	1872–1873	A. Colvard.
	1873	James M. Shannon.
Clarksville	1859–1861	Jarvis Van Buren.
	1859	Col. J. R. Stanford.
Covington	1859–1861	Benjamin F. Camp.
Culloden	1852–1853	John Darby.
Cuthbert	1860	Charles C. Seavey.
Dalton	1861	J. R. McAfee.
Darien	1849	Charles Grant.
Factory Mills	1857	F. T. Simpson.
Gainesville	1872–1873	Dr. M. F. Stephenson.
	1872–1873	W. T. Grant.
Hillsborough	1857–1859	Eli S. Glover.
LaFayette	1871–1873	A. R. McCutchen.
Macon	1868–1869, 1872	Miss L. J. Whitney.
	1868	John A. Rockwell.
	1868–1869	J. F. Adams.
	1869	Miss S. M. Proctor.
Madison	1854	Prof. William D. Williams.
Milledgeville	1849	J. M. Cotting.
	1849	Prof. C. W. Lane.
Penfield	1852	Prof. J. E. Willet.
	1869–1873	Prof. Shelton P. Sanford.
Perry	1851–1852	Dr. George F. Cooper.
Philomath	1857	James M. Reed.
Powellton	1852	P. C. Pendleton.
Quitman	1870–1873	John L. Cutter.
Saint Mary's	1870–1873	Ebenezer Barker.
	1869–1870	H. L. Hillyer.
Sandersville	1871–1873	Horatio N. Hollifield.
Savannah	1852–1859	Dr. John F. Posey.
	1859–1861	R. T. Gibson.
Sparta	1852–1861	Dr. E. M. Pendleton.
Summerville	1868	S. E. Habersham.
The Rock	1855–1860	Dr. James Anderson.
Thomasville	1860	Rev. W. Blewitt.
Thomson	1858–1859	Dr. W. T. Grant.
Trader's Hill	1872–1873	Dr. F. M. Smith.
Whitemarsh Island	1849–1858	R. T. Gibson.
Zebulon	1857–1859	Mrs. J. T. Arnold.
Idaho.		
Cantonment Jordan	1859	W. W. Johnson.
Fort Benton	1863	M. C. Rosseau.
Fort Halleck	1864	J. H. Finfrock.
Fort Laramie	1863–1864	Col. W. O. Collins.
	1865	Dr. A. F. Ziegler.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Illinois.		
Albany	1861–1862	Warren Olds.
Albion	1857	Edgar P. Thompson.
Alton	1849	S. Y. McMasters.
	1849	Norton Johnson.
Andalusia	1866–1873	Dr. E. H. Bowman.
Athens	1851–1858	Joel Hall.
Augusta	1849–1873	Dr. S. B. Mead.
Aurora	1857–1861	Andrew J. Babcock.
	1865–1868	Dr. Abiram Spaulding.
	1868–1873	Dr. A. Spaulding and Mrs. E. D. Spaulding.
Batavia	1853–1854	Prof. William Coffin.
	1857–1861	Dr. Thompson Mead.
	1858–1859	E. Capen.
	1861–1862	Frank Crandon.
Bellville	1860–1863	N. T. Baker.
	1861	Dr. John J. Patrick.
	1862	Dr. J. J. Patrick and N. T. Baker.
Belvidere	1868–1872	G. B. Moss.
Bloomington	1859–1861	Jesse Allison.
Brighton	1855–1858	William V. Eldridge.
Carbon Cliff	1859	Mrs. William S. Thomas.
Carthage	1857	Samuel J. Wallace.
	1859	Mrs. E. M. A. Bell and S. J. Wallace.
Centralia	1865	H. A. Schauber.
Champaign	1872–1873	A. P. S. Stuart.
Channahan	1860	Rev. D. H. Sherman.
	1861	Dr. Joseph Fitch.
Charleston	1870–1871	Charles Gramesley.
Chicago	1851	Henry Falcott.
	1856–1857	G. D. Hiscox.
	1859–1873	Samuel Brookes.
	1860–1861	M. C. Armstrong and J. H. Roe.
	1860–1861, 1863	Gustave A. Boettner.
	1862	A. M. Byrne, J. H. Roe, and others.
	1862	John O. Donoghoe.
	1863–1864	Arthur M. Byrne.
	1866	Isaac A. Poole.
	1867–1873	John G. Langguth, jr.
Clinton	1864–1866	C. H. Moore.
Decatur	1869–1872	Timothy Dudley.
De Kalb	1866	John D. Parker.
Dixon	1859–1863, 1867	J. Thomas Little.
Dongola	1861–1862	Ralph E. Meeker.
Dubois	1865–1873	William C. Spencer.
Du Quoin	1864	C. Ziegler.
Edgar County	1858	J. W. Brown.
Edgington	1857–1861	Dr. E. H. Bowman.
Effingham	1869–1870	Dr. Wesley Thompson.
Elgin	1858–1861	John B. Newcomb.
Elmira	1862–1863, 1865–1873	Orestes A. Blanchard.
Elmore	1864–1871	W. H. Adams.
Evanston	1858	H. G. Meacham.
	1859–1860	Charles E. Smith.
	1864	A. D. Langworthy.
	1864	W. H. Morrison.
	1864	H. W. Scovill.
	1865	Jos. H. Gill and others.
	1866–1867	Frederick J. Huse.
	1866, 1869–1873	Prof. Oliver Marcy.
Farmbridge	1860	Elmer Baldwin.
Fremont Center	1857–1858	Isaac H. Smith.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Galena	1859–1860	Emil Hauser.
Galesburgh	1861–1872	Prof. William Livingston.
Geneseo	1873	W. F. Allan.
Golconda	1866–1870	Rev. William V. Eldridge.
Granville	1854	L. G. Edgerly.
	1857	J. L. Jenkins.
Havana	1870–1873	Joseph Cochrane.
Hazel Dell	1863–1865	Henry Griffing.
Hennepin	1868	Smiley Sheppard.
	1870–1873	Ethan Osborn.
Highland	1860–1864	A. F. Bandelier, jr.
Hillsborough	1858	John S. Titcomb.
Hoylton	1864–1865	J. Ellsworth.
	1866	O. J. Marsh.
Jacksonville	1849	Prof. William Coffin.
	1858, 1861–1864	Timothy Dudley.
Jerseyville	1872–1873	Mrs. Margaret Hamilton.
Lacon	1867	A. H. Thompson.
Lebanon	1859–1861	Prof. N. E. Cobleigh.
Loammi	1867–1868	Timothy Dudley.
Louisville	1869–1873	D. H. Chase.
Magnolia	1866–1869	Henry K. Smith.
Manchester	1854–1861	John Grant.
	1862–1865	John Grant, Miss Ellen Grant.
	1866–1870	John and C. W. Grant.
	1871–1873	John and Maggie Grant.
	1871–1873	Peter Murray.
Marengo	1856–1858, 1868	O. P. Rogers.
	1859–1863, 1865–1866	O. P. and J. S. Rogers.
	1868–1869	F. Rogers.
	1869–1873	J. W. James.
Mattoon	1871–1873	A. W. Puffer.
	1869–1871	W. E. Henry.
Monroe	1849	Silas Meacham.
Mount Sterling	1866–1873	Rev. Alexander Duncan.
Naperville	1859	Lewis Ellsworth.
	1859–1860	Milton S. Ellsworth.
Newton	1859	Rev. William V. Eldridge.
North Prairie	1862	C. H. Bryant.
Olney	1860	Rev. H. H. Brickenstein.
Oquawka	1870–1873	H. N. Patterson.
Osceola	1860–1861	Dr. J. H. Pashley.
Ottawa	1852–1861	Dr. J. O. Harris.
	1859–1860	Dr. George O. Smith.
	1860	Samuel L. Shotwell.
	1862–1870	Mrs. Emily H. Merwin.
Pana	1869–1871	Dr. Thomas Finley.
Paris	1868	C. Leving.
Pekin	1857–1865	J. H. Riblet.
Peoria	1855–1873	Dr. Frederick Brendel.
	1861–1862	M. A. Breed.
Plymouth	1852	Dr. J. B. N. Klinger.
Quincy	1849	Rev. G. B. Giddings.
	1870–1872	Frank J. Hearne.
Ridge Farm, Vermillion Co.	1868	B. C. Williams.
Riley	1856–1867	E. Babcock.
Robinson's Mills	1860	Dr. E. Brendel.
Rochelle, (Alta)	1866–1871	Daniel Carey.
Rockford	1849	William Holt.
	1872–1873	James H. Blodgett.
	1873	F. A. Ticknor.
	1872–1873	Thomas D. Robertson.
	1873	W. A. Burdick.
Sandwich	1859–1870, 1872–1873	Dr. Nahum E. Ballou.

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Name of station.	Period.	Name of observer.
South Pass	1857–1858	Frank Baker.
	1862–1866	S. C. Spaulding.
	1867–1870	H. C. Freeman.
Springfield	1865–1870	G. W. Brinkerhoff.
Sweetwater	1873	Frank V. Alkire.
Tiskilwa	1859–1863	Verry Aldrich.
Upper Alton	1851–1852	Prof. P. P. Brown.
	1853–1859	Dr. John James.
	1857	Anna James.
	1861–1864	Mrs. Anna C. Trible.
Wapella	1868–1870	T. Louis Groff.
Warrensburgh	1872–1873	Timothy Dudley.
Warsaw	1855–1873	Benjamin Whitaker.
Waterloo	1865, 1867, 1868	H. Kunster.
	1869–1870	Francis Sinn.
	1872–1873	W. H. Houne, sr.
	1870–1872	Dr. C. Jozefe.
Waukegan	1849	Dr. William Joslyn.
Waverley	1865–1866	Timothy Dudley.
Waynesville	1858–1859	Joshua E. Cantril.
West Salem	1855–1860	Henry A. Fitze.
West Urbana	1857–1859	Dr. John Swain.
Wheaton	1858–1861	Prof. George H. Collier.
Willow Creek	1859–1863	E. E. Bacon.
Willow Hill	1862	Henry Griffing.
Winnebago Depot	1858–1870	J. W. Tolman.
Woodstock	1859–1861	George R. Bassett.
Wyanet	1864	E. S. Phelps.
	1865–1873	E. S. Phelps and Miss L. E. Phelps.
York Neck	1864–1865	V. P. Gay.
Indiana.		
Annapolis	1870–1873	Mrs. Dr. B. C. Williams.
Aurora	1859, 1866–1873	Dr. George Sutton.
Balbec	1865–1866	Miriam Griest.
Beech Grove	1871–1873	W. S. Clark.
Bloomingdale	1864	W. H. Hobbs.
	1865	Miss M. A. Hobbs.
Bloomington	1868–1871	Prof. C. M. Dodd, T. H. Mallow, and others.
Cadiz	1854–1863	William Dawson.
Cannelton	1856–1861	Hamilton Smith, jr.
	1869	Palmer Smith.
	1872–1873	Aaron Evans.
Carthage	1868	Charles M. Hobbs.
Columbia	1865–1871, 1873	Dr. F. McCoy and Miss Lizzie McCoy.
Evansville	1857–1858	John F. Crisp.
	1873	Sebastian Henrich.
Fort Wayne	1849	Prof. A. C. Huestis.
	1860–1861	Miss G. Webb.
	1870–1873	R. I. Robertson.
Greencastle	1851–1854	Prof. Jos. Tingley.
	1859–1863	William H. Larrabee.
Harveysburgh	1869–1870	Mrs. Dr. B. C. Williams.
Indianapolis	1864–1865	Royal Mayhew.
	1864–1865	W. W. Butterfield.
	1866–1867	W. W. Butterfield and Mrs. Butterfield.
	1866–1868	W. J. Elstun.
	1869–1871	G. V. Wooley, E. Hadley, and R. D. Craighead, (city hospital.)
Jalapa	1868–1869	Albert C. Irwin.

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Name of station.	Period.	Name of observer.
Kendallville	1854	W. B. Coventry.
	1854	J. Knauer.
Kentland	1869–1871	Daniel Spitler.
Knightstown	1868–1873	D. Deem.
Laconia	1869–1873	Adam Crosier.
La Fayette	1854	A. H. Bixby.
	1854	H. Peters.
	1865	Isaac E. Windle.
	1869–1870	J. W. Newton.
La Porte	1849	R. M. Newkirk.
	1869–1871	Fred. G. Andre.
Leo	1861	Dr. W. W. Spratt.
Livonia	1871–1872	J. R. Howard.
Logansport	1857–1858	Charles B. Laselle.
	1859–1861	Isaac Bartlett.
	1863	Thomas B. Helm.
Madison	1854	C. Barnes.
	1864	Rev. Samuel Collins.
	1865	Oliver Mulvey.
Merom	1866–1873	Thomas Holmes.
Michigan City	1857–1858	C. S. Woodard.
	1859–1860	W. Woodbridge, B. D. Angell, H. Blake.
Milton	1853–1855	Dr. V. Kersey.
Mishawaka	1859	George C. Munfield.
Mount Carmel	1869–1873	J. A. Applegate and daughter.
Muncie	1863–1864	E. J. Rice.
	1866–1870	G. W. H. Kemper.
New Albany	1855–1858	C. Barnes.
	1859	Dr. Alex. Martin.
	1863–1865, 1869	Dr. E. S. Crozier.
New Castle	1849	Prof. Jos. Tingley.
	1863–1865	Thos. B. Redding.
New Garden	1854	Dr. H. Roberts.
New Harmony	1852–1873	John Chappelsmith.
	1849–1851, 1867	Dr. D. D. Owen.
Newport	1851	Daniel H. Roberts.
North Liberty	1872	E. L. Halleck.
Patoka	1859	A. P. Turner.
Pennville	1864	John Griest.
Rensselaer	1864–1865, 1867–1871	Dr. J. H. Loughridge.
Richmond	1849–1851	Dr. John T. Plummer.
	1851–1855, 1859–1861	W. W. Austin.
	1855–1859	Joseph Moore.
	1859–1863	John Haines.
	1862–1863	Edward B. Rambo.
	1865–1868	John Valentine.
Rising Sun	1871–1873	Thomas E. Alden.
Rockville	1859–1866	H. H. Anderson.
	1859	J. M. Tenbrock.
Shelbyville	1859–1862	J. T. Bullock.
South Bend	1851	Prof. Gardner Jones.
	1858–1859	Prof. Thomas Vagnier.
	1859	Miss G. Webb.
	1860–1863	James H. Dayton.
	1863–1865	Reuben Burroughs.
South Hanover	1849	Prof. S. H. Thomson.
Spiceland	1863–1873	Wm. Dawson.
Sweetser	1872	Albert C. Irwin.
Valparaiso	1869	Rev. Robert Beer.
Vevay	1864–1870	Charles G. Boerner.
Walnut Hills	1849	W. W. Austin.
Warsaw	1870–1871	Geo. R. Thralls.
	1871	J. W. Curtis.

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Name of station.	Period.	Name of observer.
Indian Territory.		
Armstrong Academy	1849	Prof. A. G. Moffatt.
Doaksville	1849	P. P. Brown.
Tahlequah	1849	T. B. Van Horne.
Iowa.		
Afton	1871–1873	M. V. Ashby.
Algona	1860	Dr. F. McCoy.
	1861–1865	F. McCoy and Miss E. McCoy.
	1866–1870	Philip Dorweiler.
	1867–1873	James H. Warren.
Ames	1871	Ernest Adams.
Atalissa	1867	B. Carpenter.
	1872–1873	A. M. Russell.
Bangor	1861–1863	Isaac M. Gidley.
Bellevue	1856–1860	John C. Forey.
Boonsborough	1867–1873	E. Babcock.
Border Plains	1856	G. C. and W. K. Goss.
	1857–1859	Wm. K. Goss.
Bowen's Prairie	1868–1871	Samuel Woodworth.
Burlington	1859–1860	John M. Corse.
	1866–1868	Louisa P. Love.
	1868	Mrs. James Love.
Ceres	1865–1868	John M. Hagensick.
Clarinda	1865–1866	Dr. S. H. Kridelbaugh.
	1872–1873	Kridelbaugh and Peterson.
Clinton	1856–1858	Nathan H. Parker.
	1866–1871	P. J. Farnsworth.
Cresco	1871–1873	Gregory Marshall.
Council Bluff	1871–1873	Benjamin Talbot.
Dakota	1867–1868	William O. Atkinson.
Davenport	1858	Nathan H. Parker.
	1859	A. J. Finley.
	1859	H. S. Finley.
	1860	H. S. Finley and W. P. Dunwoody.
	1861	J. Chamberlain, W. P. Dunwoody, H. H. Belfield.
	1861	Dr. Ignatius Langer.
	1862	H. H. Belfield and W. P. Dunwoody.
	1863	J. Chamberlain and W. P. Dunwoody.
	1864	J. Chamberlain.
	1865	George B. Pratt.
	1866	G. B. Pratt and Sydney Smith.
	1867–1872	D. S. Sheldon.
Des Moines	1865–1867	Rev. J. A. Nash.
Dubuque	1851-1855, 1857-1858, 1868–1871	Dr. Asa Horr.
	1854	Rev. Joshua Phelps.
	1856	Dr. W. W. Woolsey.
Durant	1871–1872	F. A. Ross.
Fairbanks	1856	Dexter Beal.
Fairfield	1856–1860	J. M. Shaffer.
	1859	Miss Sue McBeth.
Fayette	1859–1860	John M. McKenzie.
Fontanelle	1866–1868	A. F. Bryant.
	1868–1873	A. F. and Mrs. Julia A. Bryant.
Forrestville	1859–1863	Daniel Sheldon.
Fort Madison	1852–1854, 1855–1868	Daniel McCready.
Franklin	1857	Dexter Beal and W. W. Beal.
	1858	Dexter Beal.
Fort Dodge	1867–1869	C. N. Jorgenson.

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Name of station.	Period.	Name of observer.
Fort Madison	1868–1872	Daniel McCready.
	1872–1873	Miss Lucy McCready.
Grant City	1869–1873	Edwin and Mrs. Rosina Miller.
Grove Hill	1859–1860	Dexter Beal.
	1861	Dexter Beal and W. W. Beal.
	1862	Mrs. Celia Beal.
Guttenburg	1864–1866	Philip Dorweiler.
	1866–1873	James P. Dickinson.
Harris Grove	1866–1873	Jacob F. Stern.
Hesper	1860–1861	H. B. Williams.
Hopkinton	1872–1873	T. H. McBride.
Independence	1861–1867	D. S. Deering.
	1862–1866	A. C. Wheaton.
	1866–1873	Mrs. D. B. Wheaton.
	1867–1873	Dr. George Warne.
Iowa City	1856	Hermann H. Fairall.
	1857–1858	W. Reynolds.
	1861–1873	Prof. Theodore S. Parvin.
Iowa Falls	1863–1872	Nathan Townsend.
Keokuk	1853	Dr. J. E. Ball.
	1866	Prof. R. M. Taylor.
Kossuth	1862	William P. Leonard.
Lemans	1860–1861	Isaiah Reed.
	1871	A. P. Gilbert.
Lizard	1869	J. J. Bruce.
Lyons	1859–1867	Dr. A. T. Hudson.
	1862–1865	P. J. Farnsworth.
	1866	Dr. J. Messman.
Manchester	1865–1866	Allen Mead.
Maquoketa	1857	Edward F. Hobart.
Marble Rock	1867–1873	H. Wadey.
Mineral Ridge	1869–1870	J. F. Sullivan.
Monticello	1864–1866	Chauncey Mead.
	1866–1870	M. M. Moulton.
	1870–1872	Rufus P. Smith.
	1872	J. E. Janes.
Mount Pleasant	1863–1864	E. L. Briggs.
	1871	A. A. Mansfield.
Mount Vernon	1857	Prof. B. W. Smith.
	1860–1873	Prof. Alonzo Collins.
Muscatine	1849–1852, 1855–1859	T. S. Parvin.
	1853–1854	P. G. Parvin.
	1860–1864	S. Foster.
	1860	T. S. Parvin and Rev. John Ufford.
	1861–1862	Rev. John Ufford.
	1863–1873	Josiah P. Walton.
Newton	1869–1870	A. Failor.
Onowa	1864	Richard Stebbins.
Osage	1866–1867	Rev. Alva Bush.
Pella	1854–1856	E. H. A. Scheeper.
Pleasant Plain	1855–1865	Townsend McConnell.
Pleasant Spring	1858	Rev. B. F. Odell.
Plum Spring	1855	B. F. Odell and Mary G. Odell.
	1859	Rev. B. F. Odell.
Poultney	1853–1854	Dr. B. F. Odell.
Quasqueton	1853–1856	Dr. E. C. Bidwell.
Red Oak Junction	1872	E. A. Harris.
Rolfe	1868–1870	Oscar L. Strong.
Rossville	1857–1859	Carlisle D. Beaman.
Sac City	1870–1872	Daniel B. Nelson.
Sioux City	1857–1858	Dr. J. J. Saville.
	1861–1863	A. J. Millard.
Saint Mary's	1853	D. E. Read.
Vernon Springs	1861–1863	Gregory Marshall.

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Name of station.	Period.	Name of observer.
Vinton	1869	James Wood.
Washington	1861	C. R. Boyle.
Waterloo	1859–1864	T. H. Doyle.
	1864–1870	T. Steed.
Waukon	1869–1870	E. M. Hancock.
Webster City	1870–1871	Clayton J. Croft.
West Branch	1871–1872	A. M. Russell.
Whitesborough	1867–1873	David K. Witter.
West Union	1869–1873	Frank McClintock.
Kansas.		
Ames	1869–1870	John M. Cotton.
Atchison	1865–1873	Dr. H. B. Horn and Miss Clotilde Horn.
Avon	1866	Allen Crocker.
Baxter Springs	1867–1870	Ingraham & Hyland.
Baxter Springs	1871–1873	William Hyland.
Belleville	1873	O. A. A. Gardner.
	1872–1873	J. W. Raynolds.
Buffalo Creek	1872–1873	R. F. Eagle.
Burlingame	1859–1861	Lucian Fish.
	1871–1873	R. M. Hoskinson.
Burlington	1869–1870	Allen Crocker.
	1871	J. D. Parker.
Cayuga	1858	W. H. Gilman.
Celestville	1859–1860	Rev. J. H. Drummond.
Centreville	1873	Dr. J. M. G. Beard.
Council City	1857–1858	Edmund Fish.
Council Grove	1865–1873	Dr. A. Woodworth.
Crawfordville	1869–1871	Percy Daniels.
Douglas	1870–1873	Dr. W. M. Lamb.
Emporia	1862	C. F. Oakfield.
Fort Riley	1859–1860	Rev. David Clarkson.
	1862–1864	Dr. Fred. P. Drew.
	1865	Post Surgeon.
	1866	J. M. Shaffer and E. P. Camp.
Gardner	1860	G. F. Merriam.
	1861–1862	James Scott.
Holton	1867–1873	Dr. James Watters.
Hutchinson	1872	A. M. Hunt.
Independence	1872–1873	Dr. W. E. Henry.
Junction City	1862	Dr. E. W. Seymour.
Lawrence	1857–1859	G. W. Brown.
	1860–1861	W. J. R. Blackman.
	1862–1864	A. N. Fuller.
	1863–1864	W. L. G. Soule.
	1867	George W. Hollingworth.
	1868–1873	Prof. F. H. Snow.
Leavenworth	1857–1859, 1868	H. D. McCarty.
	1858–1860	E. L. Berthoud.
	1861–1862	M. Shaw.
	1866–1872	Dr. J. Stayman.
	1868	T. B. Stowell.
Lecompton	1859–1860	Dr. William T. Ellis.
	1860–1861	William A. McCormick.
	1866	David G. Bacon.
Leroy	1867, 1869–1873	J. G. Shoemaker.
Manhattan	1857–1862	Isaac T. Goodnow.
	1859–1860	Rev. N. O. Preston.
	1863	I. T. Goodnow and H. L. Denison.
	1864	Henry L. Denison.
	1865–1873	Agricultural College, B. F. Mudge, and others.

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Name of station.	Period.	Name of observer.
Mapleton	1857–1858	Dr. S. O. Himoe.
Moneka	1859	J. O. Wattles and Celestia Wattles.
Neosho Falls	1859–1861	B. F. Goss.
	1868–1870	Mrs. E. M. Groesbeck.
North Topeka	1872–1873	W. Neiswender.
Olatha	1864–1872	W. Beckwith.
Paoli	1869–1873	L. D. Walrad.
Plum Grove	1863	O. H. Brown.
Ridgeway	1863	O. H. Brown.
Rural	1872	John M. Cotton.
	1872	W. H. Cotton.
Topeka	1858	F. W. Giles.
Williamsburgh	1871–1873	D. Fogle.
Williamstown	1870–1872	John M. Cotton.
Wyandotte	1859–1860	John H. Miller.
Kentucky.		
Arcadia	1869–1872	Howard Shriver.
Ballardsville	1853–1856, 1860–1862	D. John Swain.
Bardstown	1858	John H. Lunemann.
	1859	J. H. Lunemann and Thos. H. Niles
	1860–1861	Thomas H. Niles.
Beech Fork	1860	Dr. C. D. Case.
Blandville	1871–1873	Edward W. Horr.
Bowling Green	1849–1852	J. E. Younglove.
	1852	F. C. Herrick.
Chilesburgh	1865–1873	Dr. Samuel D. Martin.
Clinton	1868–1869	Rev. T. H. Cleland.
Crab Orchard	1872–1873	John F. Tarrant.
Danville	1853–1862, 1865–1873	O. Beatty.
	1864	R. H. Caldwell.
Drennon Springs	1851	Prof. S. Y. McMasters.
Georgetown	1873	Rev. J. E. Letton.
Hardinsburgh	1859	Mrs. Mary A. Walker and J. C. Barbage.
	1860–1861	Joshua C. Barbage.
Harrodsburgh	1872	Rev. J. E. Letton.
Lexington	1854	J. D. Shane.
	1859, 1867–1869	Rev. S. R, Williams.
London	1865–1866	W. S. Doak.
Louisville	1858–1859	Rev. S. R. Williams.
	1860–1863	E. N. Woodruff.
	1869	Dr. S. D. Manly.
	1870	Dr. C. B. Blackburn.
Maysville	1852–1854	E. L. Berthoud.
Millersburgh	1853	Rev. J. Miller.
Millersburgh	1854	Rev. J. Miller, Rev. G. S. Savage
	1855–1862	Dr. George S. Savage.
Newport	1861	Prof. M. G. Williams.
Nicholasville	1861–1863	Dr. Jos. McD. Matthews.
Nolin	1858	J. Grinnell.
Paducah	1859–1862	Andrew Mattison
Paris	1854–1859	L. G. Ray.
Pleasant Valley	1853	A. H. Bixby.
Prospect Hill	1849–1851	O. Beatty.
Russellville	1860	E. M. Murch.
Springdale, near Louisville	1849–1855, 1857–1872	Mrs L. Young.
Taylorsville	1866	H. C. Mathis.
Winchester	1872–1873	James M. Ogden.
Louisiana.		
Benton	1867–1870	J. H. Carter.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Cheneyville	1869–1870	R. S. Jackson.
Clear Lake	1871	George N. Leoni.
Delhi	1871–1873	Rev. T. H. Cleland.
Fall River	1859	Dr. A. W. Jackson.
Grand Coteau	1860	B. F. Anthonios.
Independence	1859	Col. C. B. Swasey,
	1860	Mrs. M. J. Mankard.
Jackson	1854	Prof. W. P. Riddell.
New Iberia	1872–1873	George N. Leoni.
New Orleans	1849–1857	Dr. E. H. Barton.
	1856–1857, 1859–1861	Lewis B. Taylor.
	1860	Dr. S. P. Moore.
	1861	Harrison Thompson.
	1867–1873	Robert W. Foster.
	1868	E. L. Raulett.
	1872–1873	Isaac Stathem
Point Pleasant	1872	Ernest Turner.
Ponchatoula	1870–1873	H. C. Collins.
Shreveport	1869–1872	Dr. J. L. Moore.
Saint Francisville	1856	B. R. Gifford.
Trinity	1856–1859	Dr. A. R. Kilpatrick.
	1856–1858, 1860	Dr. Edward Merrill.
Vidalia Plantation	1867	Rev. A. K. Teele.
Maine.		
Bangor	1849	Stephen Gilman.
	1859–1860	C. L. Nichols.
Belfast	1859–1864	G. Emerson Brackett.
Bethel	1861–1862	Rev. A. G. Gaines.
Biddeford	1849–1853	J. G. Garland.
	1854	F. A. Small.
Blue Hill	1854–1855	Rev. S. H. Merrill.
	1864	H. H. Osgood.
Brewer Village	1871–1872	E. D. Mayo.
Brunswick	1849–1859	Prof. Parker Cleaveland.
Bucksport	1849–1852	Rufus Buck.
	1871–1873	Willabe Haskell.
	1872	James Colson.
Carmel	1853–1857	J. J. Bell.
Castine	1851	Dr. J. L. Stevens.
Cornish	1855–1873	G. W. Guptill.
	1857–1873	Silas West.
Dexter	1860–1863	B. F. Wilbur
East Exeter	1858	Stephen Gilman.
East Wilton	1861–1863	Henry Reynolds & Lauriston Reynolds.
	1871–1873	Dr. Henry Reynolds.
Exeter	1860–1861	Dr. J. B. Wilson.
Foxcroft	1863–1864	M. Pitman.
Freedom	1859	E. A. Buller.
Fryeburg	1849–1856	G. B. Barrows.
Gardiner	1855–1864	Hon. R. H. Gardiner.
	1864	Rev. F. Gardiner.
	1865	Rev. F. & R. H. Gardiner.
	1866–1873	R. H. Gardiner.
Hartland	1859	E. E. Brown, S. W. Hall, L. S. Strickland, and others.
Houlton	1849	Milton Welch.
	1869–1871	Charles H. Fernald.
Lee	1866–1867	Benjamin H. Towle.
	1864–1866	E. Pitman.
Limington	1859–1861	W. G. Lord.
Lincolnville	1873	J. S. Crehore.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Lisbon	1859–1872	Asa P. Moore.
Millbridge	1872	M. S. Pinkham.
Monson	1856–1859	B. F. Wilbur.
Montville	1871–1873	J. R. Clifford.
	1871–1872	A. J. Clifford.
	1871–1872	B. C. Wentworth.
New Castle	1859	C. L. Nichols.
New Sharon	1860–1862	Dr. J. F, Pratt.
North Belgrade	1859–1860	A. H. Wyman.
North Bridgeton	1860–1861	M. Gould.
North Prospect	1867	Virgil G. Eaton.
Norway	1859–1861	G. W. Verrill, jr.
Oldtown	1849–1853	Rev. S. H. Merrill.
Orland	1872–1873	Freeman H. Chase.
Orono	1870–1873	M. C. Fernald.
Oxford	1868–1873	Howard D. Smith.
Patten	1849	S. Eveleth.
Pembroke	1862	Rev. E. Dewhurst.
Perry	1853–1865	William D. Dana.
Portland	1855–1860	Henry Willis.
	1859–1861	John W. Adams.
	1872–1873	W. H. Ohler.
Rumford Point	1866–1869	Waldo Pettingill.
Sebec	1864	Edwin Pitman.
South Thomaston	1853–1854	Joshua Bartlett.
Standish	1865–1873	John P. Moulton.
Steuben	1849–1873	J. D. Parker.
Surry	1870–1873	Oscar H. Tripp.
Thomaston	1849–1852	George & Chr. Prince.
Topsham	1859–1861	Warren Johnson.
Vassalborough	1859–1863	James Van Blascom.
Warren	1859–1860	Calvin Bickford.
Webster	1865–1867	Almon Robinson.
West Waterville	1863–1873	B. F. Wilbur.
Whitehead	1849–1852	Joshua Bartlett.
Williamsburgh	1863–1873	Edwin Pitman.
Wyndham	1849–1856	Samuel A. Eveleth.
Maryland.		
Agricultural College, Prince George's County	1861–1862	Dr. Montgomery Johns.
Annapolis	1851	Prof. W. F. Hopkins.
	1855–1856	Dr. A. Zumbrock.
	1856–1872	W. R. Goodman.
	1871–1873	Naval Hospital.
Baltimore	1852, 1853	Dr. Lewis F. Steiner.
	1857–1859	Prof. Alfred M. Mayer.
Bladensburgh	1854–1864	Benjamin O. Loundes.
Catonsville	1865–1867	George S. Grape.
Chestertown	1855–1857	James A. Pearce, jr.
	1858	Prof. A. W. Clark.
	1859–1860	Rev. A. Sutton.
	1861–1864	Prof. J. Russell Dutton.
Cumberland	1849	T. C. Atkinson.
	1871–1873	E. T. Shriver.
Ellicott's City	1871–1873	H. M. Shepherd.
Ellicott's Mills	1864	Philip Tabb.
Emmittsburgh	1866–1869	Eli Smith.
	1867–1873	Prof. C. H. Jourdan,
Fallston	1870–1873	G. G. Curtiss.
Frederick	1851	Dr. Lewis F. Steiner.
	1852-1854, 1856, 1863, 1869–1872	Henry E. Hanshew.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Frederick	1865–1866	Miss H. M. Baer.
Green Spring Furnace	1872–1873	E. G. Kinsell.
Hagerstown	1852–1854	Rev. J. P. Carter.
Leitersburgh	1852	Lewis J. Bell.
	1858–1862	Jacob E. Bell.
Leonardtown	1858–1859	Dr. Alexander McWilliams.
Linwood	1871	Charles F. Hanshew.
Mount Airy	1872–1873	E. A. Vannort.
New Market	1873	H. H. Hopkins.
New Windsor	1852	Prof. J. P. Nelson.
	1854	Prof. J. F. Maguire.
Nottingham	1849	A. P. Dalrymple.
Oakland	1857–1858	L. R. Cofran.
Port Deposit	1849	Henry W. Thorp.
Reistertsown	1872–1873	Rev. R. Heber Murphy.
Ridge	1856–1857	T. G. Stagg.
Sandy Hill	1849	Isaac Bond.
Sams Creek	1871–1872	F. J. Devilbiss.
Sykesville	1849–1852	Prof. Wm. Baer.
	1853–1854	Prof. W. Baer and Miss H. M. Baer
	1855–1865	Miss H. M. Baer.
Saint Inigoes	1859–1871	Rev. James Stephenson.
	1871–1873	Jas. T. Ellicott.
Union Bridge	1864	Warrington Gillingham.
Walkersville	1849–1851	Josiah Jones.
Woodlawn	1865–1873	James O. McCormick.
Woodstock College	1870–1873	A. X. Valente.
Massachusetts.		
Amherst	1849–1873	Prof. E. S. Snell.
Baldwinsville	1863–1865	Rev. E. Denhurst.
Barnstable	1852–1853	B. R. Gifford.
Boston	1857	E. L. Smith.
	1859	E. L. Adams.
	1870	F. H. Appleton.
Bridgewater	1854	Marshal Conant.
	1856–1857	L. A. Darling.
	1858–1859	C. W. Felt and others.
	1860–1861	Normal School.
Brookline	1868	Rev. John B. Perry.
Byfield	1851	Martin N. Root.
Cambridge	1855–1858	W. C. Bond.
	1859–1860	Harvard College Observatory.
	1865–1866	Augustus Fendler.
	1868–1869	Rev. John B. Perry.
	1869–1871	Mrs. J. B. Perry.
	1871–1872	Mrs. S. H. Perry.
Canton	1857–1858	D. H. Ellis.
Chelsea	1861–1864	Naval Hospital.
Clinton	1860–1861	Dr. George M. Morse.
Danvers	1858–1859	A. W. Mack.
Duxbury	1849	James Ritchie.
Fall River	1861	Charles C. Terry.
Fitchburgh	1860–1861	George Raymond.
Florida	1857–1861	L. F. Whitcomb.
	1873	Jacob Davis.
Framingham	1849	Gustavus A. Hyde.
Georgetown	1865–1867	Henry M. Nelson.
	1867–1872	S. Augustus Nelson.
Grafton	1860–1861	Rev. William G. Scandlin.
Hinsdale	1868–1873	Rev. E. Denhurst.
Kingston	1866–1873	Guilford S. Newcomb.
Lawrence	1857–1873	John Fallon.

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Name of station.	Period.	Name of observer.
Lowell	1849–1851	Charles J. Gilliss.
Lunenburgh	1866–1873	Geo. A. Cunningham.
Lynn	1849–1852	Jacob Bachelder.
Mendon	1849	Henry Rice.
	1849–1873	Dr. John G. Metcalf.
Milton	1867–1873	Rev. A. K. Teele.
Nantucket	1853–1861	Hon. Wm. Mitchell.
New Bedford	1849–1851	Thomas Bailey.
	1853–1873	Samuel Rodman.
	1866–1867, 1871–1872	Edward T. Tucker.
	1871–1873	George S. Hart.
Newbury	1865–1873	John H. Caldwell.
Newburyport	1853–1858	Dr. H. C. Perkins.
	1873	A. S. and M. C. Jones.
North Adams, (Hoosac tunnel)	1871–1873	Benj. D. Frost.
North Attleborough	1851–1858	Henry Rice.
North Billerica	1866–1873	Rev. Elias Nason.
Plainfield	1857	Francis Shaw.
Princeton	1853–1857	Hon. John Brooks.
Randolph	1861–1862	Orrin A. Reynolds.
Richmond	1849–1863, 1865–1872	William Bacon.
Rockport	1854	R. D. Mussey.
Roxbury	1849	Benjamin Kent.
Salem	1873	E. S. Cassino.
Sandwich	1863–1865	Dr. N. Barrows.
Somerset	1872–1873	Elisha Slade.
South Groton	1859	Alfred Collin.
Southwick	1849–1857	Amasa Holcomb.
Springfield	1853–1856	Lucius C. Allin.
	1859	Francis A. Brewer.
Stockbridge	1849	Abraham S. Peet.
Taunton	1854–1857	Albert Schlegel.
Topsfield	1860–1862	Nathan W. Brown.
	1863–1864	John H. Caldwell.
	1864–1866	Arthur M. Merriam.
	1866–1873	Sidney A. Merriam.
Uxbridge	1854	Dr. James Robbins.
West Dennis	1864	Eugene Tappan.
Westfield	1854–1866	Rev. Dr. E. Davis.
West Newton	1867–1871	John H. Bixby.
Weymouth	1856–1857, 1859	Dr. N. O. Tirrell.
Williamstown	1851–1852	C. M. Freeman.
	1854	Prof. P. A. Chadbourne.
	1854–1857	D. J. Holmes, Jas. Orton, Lavalette Wilson, and others.
	1857–1859	J. McGee, C. J. Lyons, M. L. Berger, and others.
	1860–1868	Astronomical Observatory.
	1868–1872	Prof. Albert Hopkins.
Wood's Hole	1854–1855	B. R. Gifford.
Worcester	1849–1852	S. F. Haven.
	1853–1856, 1865	Dr. E. A. Smith, T. H. Rice, and others.
	1854	Dr. Geo. Chandler.
	1857–1858	John S. Sargent and others.
	1859–1864	Dr. H. C. Prentiss.
	1866–1868	Dr. Joseph Draper.
	1868–1869	Dr. Alfred E. Walker.
	1870–1873	D. T. Morrill, M. Bemis, and Daniel Lovejoy.
Michigan.		
Adrian	1870	Miss S. M. Holmes.
	1873	Jacob Breedon.

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Name of station.	Period.	Name of observer.
Alpena	1865–1873	J. W. Paxton.
Ann Arbor	1852	Dr. H. R. Schetterly.
	1855	L. Woodruff and S. Winchell.
	1870–1872	Mrs. N. H. Winchell.
Battle Creek	1849–1860	Dr. W. M. Campbell.
	1871	L. E. Wells.
Benzonia	1870–1873	Wm. Wilson.
Brest	1848–1854	Dr. Thos. Whelpley.
Brooklyn	1852–1854	Dr. M. K. Taylor.
Burr Oak	1849–1852	Charles Betts.
Central Mine	1867–1871	S. H. Whittlesey.
Clifton	1862–1863	Wm. Van Orden, jr.
Clinton	1851–1852	Elmore Wainwright.
Coldwater	1868–1871	N. C. Southworth.
Cooper	1854–1858, 1860–1862	Mrs. Octavia C. Walker.
Copper Falls	1856–1857	Chas. S. Whittlesey.
Corunna	1855	Heber Crane.
Detroit	1849	Wm. S. Raymond.
	1849–1856	Rev. Geo. Duffield.
	1858–1860	Dr. Zena Pitcher and L. S. Horton.
	1860–1863	United States Engineers.
	1861–1862	Dr. Zena Pitcher.
	1870–1873	F. W. Higgins.
Eagle River	1856	Mrs. M. A. Goff.
East Saginaw	1854	Dr. S. F. Mitchell.
Flint	1854–1855	Dr. D. Clark.
Forestville	1858	Lieut. C. N. Turnbull.
Fort Gratiot	1858–1859	Lieut. C. N. Turnbull.
Garlick	1864	Dr. Edwin Ellis.
Grand Haven	1859–1863	Heber Squier.
Grand Rapids	1849	Franklin Everett.
	1849–1851	Dr. J. Hollister.
	1854–1858	Alfred O. Currier.
	1857-1860, 1870-1873	L. H. Streng.
	1860–1861	Edwin A. Streng.
	1864	J. B. Parker.
	1865–1872	E. S. Holmes.
Grand Traverse	1854	H. R. Schetterly.
Holland	1860-1863, 1865-1870	L. H. Streng.
Homestead	1864-1867, 1869, 1870	George E. Steele.
Houghton	1865, 1866	J. B. Minick.
Howell	1849–1852	Dr. H. B. Schetterly.
Kalamazoo	1864–1867	Harmon M. Smith.
	1865–1867	Milton Chase.
	1868	Frank Little.
Lake George	1859	J. H. Foster and Edward Perrault.
Lansing	1859	Cleveland Abbe.
	1859	J. C. Holmes.
	1863–1873	Prof. R. C. Kedzie.
Litchfield	1865–1873	R. Bullard.
Lower Saginaw	1849	James G. Birney.
Macon	1870–1871	David Howell.
Manchester	1864	Dr. F. M. Reasner.
Marquette	1857	Peter White.
	1858–1861	Dr. G. H. Blaker, jr.
	1862, 1863	Dr. G. H. Blaker, jr., and F. M. Bacon.
Mill Point	1860–1862	Rev. L. M. S. Smith.
Monroe	1852, 1872, 1873	Thomas Whelpley.
	1854	Capt. A. D. Perkins.
	1855–1860	Miss H. I. Whelpley.
	1859–1861	G. W. Bowlsby.
	1861	Miss H. I. and Florence Whelpley.
	1862–1871	Miss F. E. Whelpley.

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Name of station.	Period.	Name of observer.
Monroe Piers	1859-1863	John Lane.
Muskegon	1868-1871	H. A. Pattison.
New Buffalo	1857-1862	J. B. Crosby.
Northport	1865-1873	Rev. Geo. N. Smith.
Old Mission	1869	C. P. Avery.
Olivet	1870-1873	Prof. A. F. Kemp.
	1873	Prof. O. Hosford.
Ontonagon	1859-1863	H. Selby.
	1865-1873	Dr. Edwin Ellis.
Ottawa Point	1859-1861	John Oliver.
Otsego	1859-1862	Matthew Coffin.
	1861, 1868-1870	Dr. Milton Chase.
Oshtemo and elsewhere	1864-1873	Henry H. Mapes.
Pennsylvania Mine	1868-1869	Richard H. Griffith.
Pleasonton	1868, 1870	Joseph D. Millard.
Pontiac	1864	James A. Weeks.
Port Huron	1857-1859	James Allen, jr.
	1860, 1873	George A. Stockwell.
Redford Center	1861	Dr. Charles C. Smith.
Romeo	1855	Isaac Stone.
	1856	Seth L. and G. P. Andrews.
	1855-1857	Dr. S. L. Andrews.
Saugatuck	1854-1856	L. H. Strong.
Saint James	1853-1856	James J. Strong.
South Haven	1872	O. C. Lathrop.
Sugar Island	1863	United States Engineers.
Tawas City	1861-1863	United States Engineers.
Thunder Bay	1859-1863	I. I. Malden.
Traverse City	1872-1873	S. E. Wait.
Ypsilanti	1859	Miss G. Webb.
	1859-1863	C. S. Woodward.
Minnesota.		
Afton	1865-1867, 1869-1870	Dr. B. F. Babcock.
	1871-1872	A. L. Roe.
Beaver Bay	1858-1859	Thomas Clark.
	1859-1860	Henry Wieland.
	1860	Thomas Clark and C. Wieland.
	1861-1873	C. Wieland.
Bonniwell's Mills	1872-1873	Solomon Pendergrast.
Bowles's Creek	1865-1866	Andrew Stouffer.
Buchanan	1857-1858	Stephen Walsh.
Burlington	1858-1860	A. A. Hibbard.
Cass Lake	1852	Alonzo Barnard.
Cass Lake Mission	1856	Rev. B. F. Odell.
Chatfield	1859-1861	T. F. Thickstun.
Danville	1868	Thomas A. Kellett.
Excelsior	1873	O. O. and M. E. Jaquith.
Fond du Lac	1849-1851	Rev. Joseph W. Holt.
Forest City	1859-1861	A. C. Smith.
	1862-1866	Henry L. Smith.
Fort Ripley	1854	Rev. S. W. Maundy.
Grand Portage	1867	Richard Bardon.
Hastings	1859-1861	T. F. Thickstun.
Hazelwood	1855-1858	S. R. Riggs.
Hennepin County	1864-1865	J. B. Clough.
Holding's Ford	1869-1873	Thomas M. Young and Mary H. Young.
Itasca	1860-1861, 1863	O. H. Kelley.
Lac qui Parle	1852-1853	Rev. S. L. Riggs.
	1854	S. R. and A. L. Riggs.
Lake Winnebagoshish	1859	Rev. Benjamin F. Odell.
Lapham	1857	E. M. Wright.

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Name of station.	Period.	Name of observer.
Lapham	1858	J. F. McMullen and D. F. Shortwell.
Leech Lake	1858	Samuel Locke.
	1871	H. McMahon.
Litchfield	1870–1872	H. L. Wadsworth.
Madelia	1869–1870	W. W. Murphy.
Mankato	1864	W. Kilgore.
Minneapolis	1864–1873	W. Cheney.
New Ulm	1864–1873	Charles Roos.
Oak Lake	1869–1873	Dr. D. Pyle.
Pajutazee	1859–1862	Rev. S. R. Riggs.
Pembina	1852	Charles Cavileer.
Princeton	1856–1860	O. E. Garrison.
	1860	S. M. Byers.
Red Lake	1853–1854	Rev. E. W. Carver.
Red Wing	1856	Rev. Jabez Brooks.
	1867	Prof. A. M. Stephens.
	1872–1873	Prof. J. W. Beaman.
Rochester	1869	Alfred Milmine.
Sandy Lake	1852	Samuel Spates.
Sauk Center	1868–1869	Smith Bloomfield.
Sibley	1865–1867	C. W. Woodbury.
	1868–1873	C. W. and C. E. Woodbury.
Smithfield	1868	B. C. Livings.
Stillwater	1858	A. Van Voorhies.
Saint Anthony	1872–1873	Prof. and Mrs. N. H. Winchell.
Saint Anthony's Falls	1854	C. F. Anderson.
Saint Cloud	1861–1862, 1869	O. E. Garrison.
Saint Joseph	1853–1855	Rev. D. B. Spencer.
Saint Paul	1862–1873	Rev. A. B. Paterson.
	1866–1867	John W. Heimstreet.
Tamarack	1863–1864	Mary A. Grave.
Traverse des Sioux	1849–1851	Rev. R. Hopkins.
Wabashaw	1857–1858	Spencer L. Hillier.
Waterford	1873	J. S. Nichols.
Whitewater	1871–1873	J. K. P. Winters.
Mississippi.		
Baldwin	1871–1872	Dr. S. H. Jennings.
Brookhaven	1867–1873	T. J. R. Keenan.
	1869–1870	Thomas B. Moore.
Clinton	1870–1871	R. S. Jackson.
Columbus	1855–1859, 1869–1871	James S. Lull.
	1871–1872	John F. Tarrant.
Como	1849	E. W. Beckwith.
Early Grove	1870	W. M. Abernethy.
Enterprise	1869–1873	Rev. E. S. Robinson.
Fayette	1866–1867	Rev. T. H. Cleland.
	1873	Rev. G. C. Armstrong.
Gainesville	1849	Charles A. Folsom.
Garlandsville	1853–1855	Rev. E. S. Robinson.
Grandville	1849	James H. Vincent.
Grenada	1854	William Henry Waddell.
	1859–1860, 1866–1870	Prof. Albert Moore.
	1870	R. S. Ringgold.
	1870–1873	J. S. Payne.
Hernando	1859, 1860	William M. Johnston.
Holly Springs	1870–1872	Thomas B. Coleman.
Jackson	1849–1852	Thomas Oakley.
	1854	A. R. Green.
Kingston	1866–1867	J. Edward Smith.
Marion	1868–1873	Dr. T. W. Florer.
McLeod's	1849	David Moore.

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Name of station.	Period.	Name of observer.
Monticello	1860–1861	J. R. Cribbs.
Natchez	1849–1851	George L. C. Davis.
	1856	J. Edward Smith.
	1858–1861, 1864–1866	R. McCary.
	1866–1870	W. McCary.
Oxford	1854–1856	Prof. L. Harper.
Pass Christian	1860	Rev. J. S. Sheppard.
Paulding	1859–1861	Rev. E. S. Robinson.
Philadelphia	1870–1871	L. A. Bowden.
Port Gibson	1855–1857	Prof. J. Boyd Elliott.
Prairie Line	1859–1861	Rev. E. S. Robinson.
Vicksburgh	1849–1852	A. L. Hatch.
Wasson	1872	James S. Fithie.
	1873	Joseph Peake.
Westville	1859–1860	J. R. Cribbs.
Yazoo City	1860–1861	Col. C. B. Swasey.
Missouri.		
Allenton	1865–1871	Aug. Fendler.
Alton	1873	J. B. Rideout.
Athens	1864–1866	John T. Caldwell.
Atlanta	1873	Kentner and Muscott.
Augustus	1859	Conrad Mallinckrodt.
Bethany	1859–1860	D. J. Heaston.
Bolivar	1859–1861	W. J. Vankirk.
	1868–1870	James A. Race.
Booneville	1859–1861	Norris Sutherland.
Canton	1861–1869	George P. Ray.
	1868	Dr. J. M. Parker.
Cape Girardeau	1856–1858	Rev. James Knoud.
Carrollton	1859	John Campbell.
	1859	S. J. Huffaker.
	1860	D. J. Kirby.
Cassville	1859–1861	M. L. Wyrick.
Cave Spring	1871–1872	T. W. Coltrane.
Corning	1870–1873	Horace Martin.
Dry Ridge	1854–1855	O. H. P. Lear.
Dundee	1859–1861	S. S. Bailey.
Easton	1864–1866	P. B. Sibley.
East Prairie	1869	Adam Miller.
Edinburgh	1866–1867	John E. Vertrees.
Edina	1859–1866	J. C. Agnew.
El Dorado	1873	R. P. Edgington.
Emerson	1859	W. B. Kizer.
Farmington	1859	Nathan P. Force.
Fort Pierre	1854	Frederick Behmer.
Gallatin	1872–1873	Arthur H. Weston.
Greenfield	1859–1862	Dr. S. B. Bowles.
Greenville	1859–1860	O. D. Dalton.
Hannibal	1853	O. H. P. Lear.
	1855–1856	Dr. Edward Duffield.
Harrisonville	1859–1870	John Christian.
Hematite	1868–1871	John M. Smith.
Hermann	1859–1860	Philip Weber.
Hermitage	1867–1869	Miss Belle Moore.
High Hill	1873	W. S. Chapin.
Hornersville	1859–1861	W. H. Horner.
Jefferson City	1868–1872	Nicholas De Wyl.
Kansas City	1870–1873	S. W. Salisbury.
Keytesville	1869	Charles Veatch.
	1871	John P. Jones.
	1873	H. H. Mann.
Kirksville	1859	Dr. Robert Byers.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Kirksville	1859–1863	J. H. Myers.
Laborville	1863–1864	William Muir.
Lancaster	1859	John M. Weatherford.
Lexington	1859	Joseph A. Wilson.
	1860	George W. Wilson, jr.
Luray	1859–1861	B. P. Hanan.
Mount Vernon	1871–1873	Wyatt Harris.
Nevada	1871–1873	P. J. Bond.
Osborne City	1873	Rev. R. B. Foster.
Oregon	1867–1872	William Kaucher.
Paris	1859–1862	W. F. Maxey.
Rhineland	1859–1860	Charles Vogel.
Richland	1872–1873	Spencer L. Goodwin.
Richmond	1859–1860	R. W. Finley.
Rockport	1855–1856	Dr. C. Q. Chandler.
Rolla	1867–1873	Homer Ruggles.
Springfield	1857–1858	J. A. Stephens.
Saint Joseph	1857–1858	Edward B. Neely.
	1869–1873	Rev. Henry Bullard.
Saint Louis	1853–1857, 1859–1867	Dr. George Engelmann.
	1856–1857	Dr. A. Wislizenus.
	1858	Drs. G. Engelmann and A. Wislizenus.
	1859–1864	Augustus Fendler.
	1860–1862, 1864	J. H. Lunemann.
	1861	Rev. P. W. Koning.
	1865–1868	Rev. F. H. Stuntebeck.
	1868–1869	Rev. I. Straetmans.
	1870–1872	A. Averbeck.
	1872	Bertram D. Kribbin.
	1872–1873	C. J. B. Leib.
Stockton	1859–1861	William Wells.
Stoutland	1873	E. D. Denny.
Sycamore Springs	1873	A. T. Hubbard.
Toronto	1859–1860	B. D. Dodson.
Trenton	1859	Thomas J. Conkling.
Tuscumbia	1859	William M. Lumpkin.
Union	1866	Dr. W. Moore.
	1867	Miss Belle Moore.
Warrensburgh	1868–1869	Rev. J. E. Pollock.
	1870	S. K. Hall.
Warrenton	1859	Marion F. Hamaker.
	1859–1863	Mary A. Tidswell.
Waynesville	1859	B. G. Lingon.
Westport	1851	Rev. N. Scarritt.
Wet Glaze	1872–1873	A. Y. Carlton.
Willard	1870–1872	R. H. McCord.
Montana.		
Benton City	1868	Dr. H. M. Lehman.
	1869	S. V. Clevenger.
Camp Cooke	1867	Dr. H. M. Lehman.
Cantonment Wright	1861–1862	T. Koleski.
Deer Lodge City	1869–1873	Granville Stuart.
Helena City	1866–1868	Alexander Camp Wheaton.
Missoula	1870	J. P. Reinhard.
	1870–1873	J. M. Minesinger.
Virginia City	1871	Edward N. Goddard.
Nebraska.		
Beatrice	1873	W. F. Ware.
Bellevue	1854	D. E. Reed.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Bellevue	1857-1867	Rev. William Hamilton.
	1857	Henry M. Burt.
	1868-1873	Miss E. E. Caldwell.
Blackbird Hills	1867-1873	Rev. Willam Hamilton.
Blair	1873	P. F. Peterson.
Brownville	1858-1860	Charles B. Smith.
Dakota City	1867-1869	H. H. Brown.
Decatur	1869	Dr. G. C. Case.
Deer Creek	1859	Maj. Thomas S. Twiss.
De Soto	1867-1873	Charles Seltz.
Elkhorn City	1858-1864	Anna M. J. Bowen.
	1865-1870	John S. Bowen.
Emerson	1871-1873	William Dunn.
Fontanelle	1859, 1862, 1863	John Evans.
	1868-1869	Henry Gibson.
Fort Pierre	1860-1861	M. C. Rousseau.
Fort Union	1854	E. T. Denig.
Glendale	1861, 1866-1867	Dr. A. L. Child.
	1868-1869	Dr. A. C. Child, Miss J. E. Child.
Jonin	1865	L. J. Hill.
Kenosha	1859-1862	Bela White.
Lincoln	1870	G. A. Goodrich.
Nebraska City	1859	Edgar E. Mason.
	1868-1871	P. Zahner.
	1869-1871	J. M. Pettenger.
Newcastle	1870-1872	Lewis H. Smith.
Norfolk	1873	Lewis Sessions.
Nursery Hill	1865	R. O. Thompson.
Omaha	1857-1859	William N. Byers.
	1859-1860	John G. Rain.
	1860-1861	James P. Allan.
	1868-1869	C. B. Wells.
Peru	1867-1869	J. M. McKenzie.
Plattsmouth	1873	A. J. Clark.
Red Cloud	1872-1873	Edward Kellogg.
Rock Bluffs	1860-1861	H. C. Pardee.
Santee Agency	1871-1873	George S. Truman.
South Pass Wagon-road expedition	1859-1860	C. H. Miller.
Nevada.		
Star City	1865	R. C. Johnson.
New Hampshire.		
Antrim	1866-1868	Rev. William Hurlin.
Claremont	1857-1858	F. N. Freeman.
	1859-1868	Arthur Chase.
	1864-1867	Stephen O. Mead.
	1867-1868	Linus Stevens.
Concord	1849-1857	Dr. William Prescott.
	1857-1858	H. E. Sawyer.
	1858	E. P. Colby.
	1865-1870	John T. Wheeler.
	1868	James C. Knox.
Dublin	1849, 1851-1852	Rev. L. W. Leonard.
Dunbarton	1868-1873	Alfred Colby.
Exeter	1849, 1851-1852	Rev. L. W. Leonard.
	1861-1865	Rev. Elias Nason.
Farmington	1860-1861	Louis Bell.
Francestown	1857	Dr. Martin N. Root.
	1857-1858	A. H. Bixby.
Gorham	1872	E. S. Mason.

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Name of station.	Period.	Name of observer.
Great Falls	1854–1857	Henry E. Sawyer.
Hanover	1853–1854	Prof. Ira Young and A. S. Young.
Isle of Shoals	1849	Thomas B. Laighton.
Laconia and Lake Village	1857–1861	J. W. French, agent L. W. C. and W. M. Co.
Littleton	1863–1864	Robert C. Whiting.
Londonderry	1849–1857	Robert C. Mack.
London Ridge	1862–1865	Dr. Isaac S. French.
Manchester	1852–1857–1859–1861	Hon. S. N. Bell.
Mount Washington	1859	Joseph H. Hall.
	1870–1871	J. H. Huntington.
North Barnstead	1855–1858	R. F. Hanscom.
	1860–1869	Charles H. Pitman.
North Littleton	1859–1860, 1863–1864	Rufus Smith.
Portsmouth	1849	Dr. C. Chase.
	1867–1868	John Hatch.
Saint Thomas	1871	Daniel Bonelli.
Salisbury	1870–1873	E. D. Couch.
Salmon Falls	1853–1854, 1856	George B. Sawyer.
Shelbourne	1856–1873	Fletcher Odell.
	1872–1873	John Collin.
Stratford	1859–1873	Branch Brown.
South Antrim	1868–1872	Rev. William Hurlin.
Tamworth	1867, 1869–1873	Alfred Brewster.
Wentworth	1859	Peter L. Hoyt.
West Enfield	1856–1858	Nathaniel Purmort.
Whitfield	1869–1873	L. D. Kidder.
New Jersey.		
Allowaystown	1871–1873	H. C. Perry.
Atco	1871–1873	H. A. Green.
Belleville	1849	Thomas B. Merrick.
Bloomfield	1849–1858, 1862–1863	R. L. Cooke.
Burlington	1849–1854	Prof. Adolph Frost.
	1855–1858	Dr. E. R. Schmidt.
	1856	Prof. A. Frost and Dr. E. R. Schmidt.
	1863–1868	John C. Deacon.
Camden	1870	Isaac C. Martindale.
Cinnaminson	1859–1860	William Parry.
Cole's Landing	1864–1866	James S. Lippincott.
Dover	1866–1869	Howard Shriver.
Elwood	1867–1868	J. S. Fritts.
Freehold	1857–1858	B. F. Simpson and S. R. Willis.
	1859–1862	O. R. Willis.
Greenwich	1856–1861	Benjamin Sheppard.
	1864	Clarkson Sheppard.
	1865–1867	C. Sheppard and Miss R. C. Sheppard.
	1868–1873	Miss R. C. Sheppard.
Haddonfield	1849	John Clement, jr.
	1866–1869	Samuel Wood.
	1869	John Boadle.
Haddonfield	1870	J. L. Lippincott.
Jersey City	1871–1872	Thomas T. Howard, jr.
	1873	Thos. T. Howard, jr., and wife.
Lambertville	1849	Jacob S. Gary.
	1873	Geo. H. Larison.
Long Branch	1861–1863	Howard A. Stokes.
	1865	Arch'd Alexander.
Morristown	1849–1861	Dr. S. C. Thornton.
	1859	Miss E. E. Thornton.
	1865–1873	Thos. J. Beans.
	1865	Jos. W. Lippincott.

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Name of station.	Period.	Name of observer.
Mount Airy	1869–1873	John Fleming.
Mount Holly	1861–1868	Dr. Morgan J. Rhees.
Newark	1849–1873	W. A. Whitehead.
New Brunswick	1854, 1865–1868	Prof. Geo. H. Cook.
	1854	Eli T. Mack.
	1859	Edwin Allen.
	1860	Edwin Allen and G. W. Thompson.
	1861–1865	G. W. Thompson.
	1869–1870	Isaac E. Hasbrauck.
Newfield	1867–1870	E. D. Couch.
New Germantown	1868–1873	Arthur B. Noll.
Newton	1868–1869	Dr. Thos. Ryerson.
Orange	1872–1873	Dr. W. Hamilton Stockwell.
Passaic Valley	1863–1865	Wm. Brooks.
Paterson	1866–1871	Wm. Brooks.
Progress	1863–1865	Thos. J. Beans.
Readington	1866–1867, 1869–1873	John Fleming.
	1873	Robins Fleming.
Riceville	1860–1861	Prof. L. Harper.
Rio Grande	1868–1873	Jerusha R. Palmer.
Salem	1856	C. M. Dodd.
	1859	George Watson.
Seaville	1865–1867	Barker Cole.
	1868	E. C. Cole.
Sergeantsville	1857–1858	John T. Sergeant.
South Orange	1870–1873	Dr. W. J. Chandler.
Trenton	1865–1873	Ephraim R. Cook.
Vineland	1867–1873	Dr. John Ingram.
Woodstown	1860	George Watson.
New Mexico.		
Pope's expedition	1855–1857	James M. Reade.
New York.		
Adams Center	1859–1861	Dr. C. D. Potter.
Albany	1865–1866	Dr. H. M. Paine.
Albion	1849–1854	L. F. Munger.
Alps	1849–1851	James H. Ball.
Angelica	1854–1858	E. M. Alba.
	1871–1873	C. P. Arnold.
Ardenia	1868–1873	Thomas B. Arden.
Auburn	1860–1865	John B. Dill.
Baldwinsville	1849–1867	John Bowman.
Bannaville	1870	G. S. France.
Beaver Brook	1853–1854	C. S. Woodward.
Bellport	1857–1862	H. W. Titus.
Beverly	1853–1859	Thos. B. Arden.
Blackwell's Island	1855–1857	Dr. W. W. Sanger.
Breslau	1872–1873	Frank Miller.
Brookhaven	1868–1873	E. A. Smith and daughters.
Brooklyn	1870–1873	Isaac P. Mailler.
	1872–1873	R. W. Johnson.
Buffalo	1849–1852	A. Hosmer.
	1853–1854, 1860	Elias O. Salisbury.
	1854	Dr. S. B. Hunt.
	1854	W. D. Allen.
	1858–1862, 1866–1873	William Ives.
	1860–1863	United States Engineers.
Caldwell	1870	Alex. M. Strong.
Canton	1853–1858	E. W. Johnson.
	1871–1873	Leslie A. Lee.
	1873	J. C. Lee.

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Name of station.	Period.	Name of observer.
Carlton	1873	W. P. Godfrey.
Cazenovia	1856–1864	Prof. Aaron White.
	1865, 1867–1873	Prof. Wm. Soule.
Charlotte	1859–1863	Andrew Mulligan.
Chatham	1849–1851	Cornelius Chase.
	1853–1854	C. Thornton Chase.
Clinton	1856	Prof. O. Root.
	1857–1859, 1862–1865	Dr. H. M. Paine.
Clockville	1849	J. P. Chapman.
Clyde	1859–1862	Matthew Mackie.
Constableville	1852	L. L. Fairchild.
Constantia	1861	Sereno Clark.
Cooperstown	1869–1873	G. Pomeroy Keese.
Dansville	1859–1861	Rev. John J. Brown.
Depauville	1865–1873	Henry Haas.
East Franklin	1854	Dr. J. W. Smith.
East Henrietta	1859–1862	A. S. Wadsworth.
Eden	1855	Stephen Landon.
	1857–1859	Anna S. Landon.
Fairfield	1871	W. A. Brownell.
	1871–1872	G. F. Sawyer.
Falconer	1853–1854	Laurens A. Langdon.
Farmer	1859	A. B. Covert.
Farmingdale	1868–1872	John C. Merritt.
Fishkill Landing	1855–1866	W. H. Denning.
Flatbush	1854–1855	Rev. Thos. H. Strong.
	1856–1860	Rev. R. D. Vankleck.
	1860	Rev. W. W. Howard.
	1862–1873	Rev. E. T. Mack.
Fordham	1856	John Aubier.
	1856–1857	Claudius Pernot.
	1858	Dr. H. M. Paine.
	1859–1862, 1864	Rev. John Aubier and Prof. A. T Monroe.
Fort Ann	1863–1866	P. A. McMore.
Fort Edward	1857–1859	Prof. Solomon Sias.
	1869–1871	J. De Witt Miller.
Fort Niagara	1859–1863	L. Leffman.
Fredonia	1854–1864	Prof. D. J. Pratt.
Friendship	1866–1867	George W. Fries.
Garrison's	1860–1861, 1863–1868	Thos. B. Arden.
Geneva	1855–1857, 1864–1868	Rev. W. D. Wilson.
	1859	Job Elleston.
Germantown	1859	Wm. Tompkins.
	1866–1873	Rev. Sanford W. Roe.
Glasco	1869–1873	D. B. Hendricks.
Gouverneur	1852–1854	Dr. P. O. Williams.
	1860–1873	Cyrus H. Russell.
Glen's Falls	1854	Warren P. Adams.
Great Valley	1859–1860	Kathalo Kelsey.
Groton	1872	Rev. Samuel Johnson.
Havana	1859–1860	Col. E. C. Frost.
Hector	1865–1867	David Trowbridge.
	1871–1873	Chas. E. Adriance.
Hempstead	1873	J. W. Johnson.
Hermitage	1860–1862	A. A. Hibbard.
Homer	1855–1857	Edwin C. Reed.
Houseville	1849-1854, 1856-1860, 1865–1872	Walter D. Yale.
Hudson	1869	G. P. Hachenberg.
Hungerford College Institute	1872–1873	A. B. Watkins and R. S. Bosworth.
Institution for Deaf & Dumb	1849–1868	Prof. Oran W. Morris.
Ilion	1859–1860	J. D. Ingersoll.
Jacksonville	1873	F. D. Carman.

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Name of station.	Period.	Name of observer.
Jamestown	1863–1866	Rev. Sanford W. Roe.
	1871–1873	S. H. Albro.
	1871–1873	Samuel G. Love.
Jericho, L. I.	1849	Albert G. Carll.
Kensico	1873	C. J. McIlvaine.
Lake	1856–1858	Peter Ried.
Leroy	1854	L. F. Munger.
Leyden	1868	C. C. Merriam.
Liberty	1855–1866	John Felt.
Lima	1861	Prof. S. A. Lattimore.
Little Genesee	1866–1873	Daniel Edwards.
Lockport	1849	E. Giddings.
	1870–1873	B. Wheaton Clark.
	1849–1852	James B. Trevor.
Locust Grove	1869–1870	C. C. Merriam.
Lodi	1849–1858	John Lefferts.
Lowville	1854	Irah R. Adams.
	1854–1858	J. Caroll House.
	1871	A. Judson Barrett.
	1871–1872	Rev. William Irish.
Ludlowville	1868	C. P. Murphy.
Lyons	1859–1862	Dr. E. W. Sylvester.
Madrid	1849–1859	E. A. Dayton.
Marathon	1863	Lewis Swift.
McGrawville	1856–1857	J. Metcalf Smith.
Mexico	1855–1857	John R. French.
Milo	1869–1872	Gilbert D. Baker.
Minaville	1867	D. S. Bussing and J. W. Bussing.
	1868–1872	J. W. Bussing.
Mohawk	1861–1868	James Lewis.
Morristown	1859	William Day.
Moriches	1864–1867	E. A. Smith and Miss N. Smith.
Morley	1849	Ezra Parmelee.
Newark Valley	1868–1872	Rev. Samuel Johnson.
Newburgh	1864–1871	James H. Gardiner.
New York	1849	U. S. Naval Station.
	1854	J. S. Gibbons.
	1854–1855	S. De Witt Bloodgood.
	1854–1861	Caleb Swann and Dr. J. P. Loines.
	1860–1861	Frederick I. Slade.
	1860–1863	Charles C. Wakely.
	1860–1872	Naval Hospital.
	1863–1866	E. B. Cook.
	1865–1867	Rev. John M. Aubier.
	1869–1870	Mrs. M. M. Marsh.
	1865–1870	Prof. Charles A. Joy.
	1868–1873	Prof. Oran W. Morris.
	1867–1868	Haden Patrick Smith.
North Argyle	1864, 1870–1873	George M. Hunt.
North Hammond	1866–1873	Charles A. Wooster.
North Salem	1849–1853	John F. Jenkins.
	1855–1856	Mrs. M. J. Lobdell.
North Volney	1868–1873	J. M. Partrick.
Nichols	1857–1873	R. Howell.
Nyack	1869	C. de la Verny.
Ogdensburgh	1849–1852, 1854–1863	W. E. Guest.
Oneida	1864–1873	Dr. Stillman Spooner.
Oswego	1849	C. Strong.
	1851–1854	J. H. Hart.
	1854–1872	Capt. W. S. Malcolm.
Otto	1861	Prof. Weston Flint.
Ovid	1855–1858	J. W. Chickering.
Palermo	1868–1873	Erastus B. Bartlett.
Palisades	1868	W. S. Gilman, jr.

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Palmyra	1864–1865	Stephen Hyde.
Peekskill	1854	Charles A. Lee.
Penn Yan	1854–1857–1859	Dr. H. P. Sartwell.
Perry City	1864	David Trowbridge.
Philipstown	1851–1852	Thomas B. Arden.
Pine Hill	1859–1860	Godfrey Zimmerman.
Plainville	1856–1857	J. H. Norton.
Plattsburgh	1855–1857	Joseph W. Taylor.
Pompey	1857–1858	S. Marshall Ingalls.
Pompey Hill	1856	John F. Kendall.
Potsdam	1872	Hon. J. Welch.
Poughkeepsie	1849	Prof. C. B. Waring.
	1870	Miss Swallow.
Rochester	1849	Prof. Wetherell.
	1855–1867	Prof. C. Dewey.
	1859–1867	Prof. M. M. Matthews.
	1868–1870	H. Wells Mathews.
	1871–1872	Dr. G. P. Hachenberg.
	1868–1870	W. M. L. Fisk.
Rockville Center	1873	S. P. Probasco.
Rodman	1873	Rev. Samuel Johnson.
Sacket's Harbor	1849	U. S. Naval Station.
	1851–1852	Mandrin Linus.
	1859–1863	H. Metcalf.
Sag Harbor	1849–1858	E. N. Byram.
Saratoga	1856–1859	Walter H. Riker.
Saugerties	1863–1866	R. G. Williams.
	1859–1860	James W. Grush, James M. Alexander, and L. S. Packard.
Schenectady	1864	Robert M. Fuller and Haren V. Swart.
	1858–1859	Alexis A. Julien and H. A. Schauber.
Seneca Falls	1849	Elisha Foote.
	1849–1852	John P. Fairchild.
	1853–1854	Charles A. Avery.
	1861–1864	Philo Cowing.
Sennett	1857	Henry B. Fellows.
Sherburne	1865	Rev. James R. Haswell.
Sing Sing	1849–1852	C. F. Maurice.
Skaneateles	1860–1867	W. M. Beauchamp.
Sloansville	1868–1870	G. W. Potter.
Smithville	1849–1852, 1854–1856	J. Everett Breed.
Somerville	1849–1851	Dr. F. B. Hough.
South Edmeston	1849–1851	L. A. Beardsley.
South Hartford	1863–1873	G. M. Ingalsbe.
South Trenton	1863–1873	Capt. Storrs Barrows.
Spencertown	1855–1857	A. W. Morehouse.
	1858	Irving Magee.
	1861	Levi S. Packard.
Springville	1849	J. W. Earle.
	1851	Moses Lane.
Stapleton	1867–1868	Spencer L. Hillier.
Suffern	1863	James H. Warren.
Syracuse	1851–1852	Henry L. Dinsmore.
Theresa	1861–1868	S. O. Gregory.
Throg's Neck	1864–1866	Francis M. Rogers.
	1865–1872	Miss Elizabeth Morris.
Troy	1849–1872	John W. Heimstreet.
	1853–1854	Prof. E. A. H. Allen.
	1856–1857	Prof. Dascom Greene.
	1860–1861	William L. Haskin.
Utica	1856.1857, 1868	Dr. L. Tourtellot.
Vermillion	1860–1868	E. B. Bartlett.

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Name of station.	Period.	Name of observer.
Virgil	1873	J. E. Winslow.
Wales	1854	S. O. Carpenter.
Wampsville	1853–1863	Dr. Stillman Spooner.
Warrensburgh	1871	Randolph McNutt.
Warsaw	1865	J. P. Morse.
Waterburgh	1868–1873	David Towbridge.
Waterford	1856–1863	John C. House.
Watertown	1855–1857	Dr. P. O. Williams.
Waterville	1849–1851	James M. Tower.
Wellsville	1857, 1858, 1860	H. M. Sheerer.
West Concord	1856, 1857	Lewis Woodward.
West Day	1858–1859, 1871–1873	Jude M. Young.
West Farms	1856–1857	J. S. Gorton.
West Morrisania	1857–1859	I. Zaepffel.
White Plains	1862–1873	O. R. Willis.
Wilson	1858–1864	E. S. Holmes.
North Carolina.		
Albemarle	1872	S. J. Pemberton.
Anandale	1870–1872	W. H. Murdoch.
Asheville	1857–1858	W. W. McDowell.
	1867–1873	E. J. Aston.
	1868–1873	Dr. J. F. E. Hardy.
Attaway Hill	1849–1862, 1867–1873	F. J. Kron.
Bakersville	1871	J. H. Greene.
Beaufort	1872	James Rumley.
Chapel Hill	1849–1861	Prof. James Phillips.
	1869–1870	David S. Patrick.
Charlotte	1871–1873	George B. Hanna.
Davidson College	1858–1859	Prof. W. C. Kerr.
Edenton	1871	A. A. Benton.
	1872	Richard N. Hines.
	1873	Margaret A. Hines.
Fayetteville	1871	John M. Sherwood.
	1871–1872	G. W. Lawrence.
Forest Hill	1872–1873	Mrs. D. D. Davis.
Franklin	1872, 1873	Albert Siler.
Gaston	1859–1861	Dr. George F. Moore.
Goldsborough	1860–1861, 1872	Prof. E. W. Adams.
Green Plains	1859	Samuel W. Westbrook.
Greensborough	1871–1873	S. S. Howard.
Guilford Mine	1867–1869	Alexander Wray.
Jackson	1852–1854	Rev. Frederick Fitzgerald.
Kenansville	1868–1870	Prof. N. B. Webster.
Lake Scuppernong	1849–1852	Rev. J. A. Sheppard.
	1851	D. Morrell.
Lenoir	1871–1873	Dr. L. Beall.
Lincolnton	1854	Dr. J. Bryant Smith.
Marlborough	1858	Robert H. Drysdale.
Mount Airy	1872	Robert S. Gilmour.
Murfreesborough	1856–1861	Rev. A. McDowell.
Murphy	1872–1873	William Beal.
New Garden	1872–1873	A. E. Kitchen.
Oxford	1866–1867	John H. Mills.
	1867–1873	Dr. William R. Hicks.
Raleigh	1859	T. Carter and W. H. Hamilton.
	1860	W. H. Hamilton.
	1866–1869	Rev. Fisk P. Brewer.
	1869	Miss M. H. Taylor.
Rutherfordton	1849	J. W. Calloway.
Statesville	1866–1873	Thomas A. Allison.
Tarborough	1871	Thomas Norfleet.
	1871–1873	Robert H. Austin.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Thornbury	1854	Rev. F. Fitzgerald.
	1854	Daniel Morelle.
Trinity College	1860–1861	Rev. B. Craven.
	1869	E. D. Pearsall.
Warrenton	1857–1858	Dr. W. M. Johnson.
	1870	Henry A. Foote.
Weldon	1872–1873	T. A. Clarke.
	1871	John A. Harrell.
Wilmington	1872–1873	Rev. Daniel Morelle.
Wilson	1867	E. W. Adams.
Ohio.		
Adams' Mills	1870–1871	C. A. Stillwell.
Amesville	1869	E. W. Brawley.
Andrews	1860–1861	Dr. W. Spratt.
Athens	1849–1851	Prof. W. W. Mather.
Austinburgh	1862–1863	J. G. Dole and C. S. S. Griffing.
	1864	David S. Alvord.
	1864	J. G. Dole.
	1864–1866	E. D. Winchester.
Avon	1858–1860	Rev. L. F. Ward.
Belle Center	1857–1859	Rev. R. Shields and J. C. Smith.
	1854, 1860–1861	Rev. Robert Shields.
Bellefontaine	1855–1860	Joseph Shaw.
	1870–1873	W. Barringer.
Berea	1854	Prof. G. M. Barber.
	1871–1872	I. McK. Pettenger.
Berlin Heights	1873	J. S. Patterson.
Bethel	1859–1873	George W. Crane.
Bowling Green	1857–1863	Dr. W. R. Peck.
	1866–1873	John Clarke.
Breckville	1859–1861	Rev. S. L. Hillier.
Cardington	1863	Hubert A. Schauber.
Carson	1871–1873	Mrs. M. M. Marsh.
Carthagena	1870–1873	Dr. R. Müller.
Centralia	1864–1866	Hubert A. Schauber.
Chester Hill	1873	John D. Wright.
Cheviot	1855–1857	Ebenezer Hannaford.
Cincinnati	1849	John Lea.
	1854, 1857–1858	F. W. Hurtt.
	1855–1873	George W. Harper.
	1859–1863	A. A. Warder.
	1859–1864	R. C. and J. H. Phillips.
	1860–1862	Eli T. Lappan.
	1865–1872	R. C. Phillips.
	1871–1873	J. H. Shields.
Cleveland	1851, 1855–1861, 1868	Gustavus A. Hayde.
	1852	Edward Wade.
	1858–1863	Edward Colburn.
	1860–1863	U. S. Engineers.
	1862–1873	G. A. Hyde and Mrs. Hyde.
	1866–1868	Dr. T. A. Smurr.
College Hill	1854	G. S. Ormsby.
	1853–1857	Prof. R. S. Bosworth.
	1858–1865	Prof. J. H. Wilson.
	1859–1873	J. W. Hammitt.
	1865–1867	L. B. Tuckerman.
Collingwood	1856–1857	Henry Bennett.
	1858	Sarah E. Bennett.
Coshocton	1861–1862	Thomas H. Johnson.
Columbus	1851–1852	Theodore G. Wormley.
Croton	1860	Mark Sperry.
	1861	Rev. E. Thompson and Mark Sperry

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Name of station.	Period.	Name of observer.
Croton	1862–1863	Rev. Elias Thompson.
Cuyahoga Falls	1864–1865	D. M. Rankin.
Dallasburgh	1859–1863	F. G. Hill.
Dayton	1856	Cooper Female Seminary.
	1856	Dr. James C. Fischer.
	1858	Lewis Groneweg.
	1873	Charles Reeve.
East Cleveland	1861–1862	Mrs. M. A. Pillsbury.
East Fairfield	1859–1867	S. B. McMillan.
East Rockport	1854	Dr. J. R. Kirtland.
Eaton	1863–1865	Thomas J. Larsh.
Edgerton	1869–1870	S. B. Knight.
Edinburgh	1857–1858	Smith Sanford.
Farmer	1871–1872	Dr. S. C. Irwin.
Franklin	1855–1857	Dr. W. L. Schenck.
Freedom	1859–1860	H. M. Davidson.
	1861	H. M. Davidson and Wilson Davidson.
	1862	Wilson Davidson.
Gallipolis	1854–1856	G. W. Livesay.
	1857–1858, 1864–1873	A. P. Rogers.
Gambier, Kenyon College	1871	C. D. Leggett and C. A. Stillwell.
	1869–1871	F. K. Dunn and others.
Garrettsville	1861–1863	Warren Pierce.
Germantown	1852–1856	L. Groneweg.
	1856–1857	J. S. Binkerd.
Gilmore	1869–1870	Samuel M. Moore.
Granville	1849	Prof. P. Carter.
	1849–1858	Dr. S. N. Sanford.
Groveport	1872–1873	August Bareis.
Harmar	1860–1861	W. G. Fuller.
Hillsborough	1851–1860, 1863–1873	Rev. J. McD. Mathews.
	1857	C. C. Janes.
	1863	Dr. C. C. Samms.
Hiram	1855	S. L. Hillier and S. M. Luther.
	1856	Spencer L. Hillier.
	1856–1860	S. M. Luther.
Hockingport	1859–1860	Dr. John Rhoades.
Homer	1852	Thomas F. Withrow.
Hudson	1858–1859	Prof. C. A. Young and E. W. Childs.
	1860–1861	Prof. C. A. Young and A. C. Barrows.
	1862	Prof. C. A. Young, E. W. Stuart, J. C. Elliott, W. Pettengill, and H. R. Watterson.
	1863	Prof. C. A. Young and J. C. Elliott.
	1871–1873	Charles J. Smith.
	1872–1873	H. L. Keenan and F. W. Taylor.
Huron	1854	Edmund W. West.
Iberia	1859	S. T. Boyd.
Jackson	1849–1854	George L. Crookham.
	1855	G. L. Crookham and M. Gilmore.
	1855	S. B. Wood.
Jackson	1857–1858	M. Gilmore.
Jacksonburgh	1868–1873	Dr. J. B. Owsley.
Jefferson	1855–1858	James D. Herrick.
Keene	1849–1852	Dr. E. C. Bidwell.
	1853–1854	E. Spooner.
Kenton	1862–1863, 1866–1873	Dr. C. H. Smith.
Kelly's Island	1859–1870	George C. Huntingdon.
	1871	D. K. Huntington.
Kingston	1863–1867	Prof. John Haywood.
Lafayette	1867	Samuel Knoble.
Lancaster	1857	Lewis M. Dayton.

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Name of station.	Period.	Name of observer.
Lancaster	1858	H. W. Jaeger.
	1859	W. E. Davis.
	1866	J. W. Towson.
Lebanon	1849	Joseph C. Hatfield.
Little Hocking	1862–1863	James Fraser.
Little Mountain	1867–1873	E. J. Ferriss.
Madison	1857–1860	Rev. L. S. Atkins.
	1859–1863	Mrs. Ardelia C. King.
Mansfield	1851–1852	F. A. Benton.
Marietta	1860–1863	D. P. Adams.
	1849–1855	Prof. J. W. Andrews.
Marion	1865–1873	H. A. True.
	1859	T. Chase.
Martin's Ferry	1867	Charles R. Shreve.
	1869–1872	C. R. and Martha B. Shreve.
Medina	1857–1858	Rev. L. F. Ward.
	1858–1863	William P. Clarke.
Middlebury	1849	Michael Beecher.
Milnersville	1862–1873	Rev. D. Thompson.
Monroe County	1859	Enoch D. Johnson.
Mount Auburn	1868–1873	Senior Class Mount Auburn Female Institute.
Mount Gilead	1871	James McCune.
Mount Pleasant	1859–1860	David H. Tweedy.
Mount Tabor	1849	William Lapham.
Mount Union	1857–1860	Newton Anthony.
Mount Vernon	1853–1855	F. A. Benton.
Mount Victory	1859–1860	W. C. Hampton.
Newark	1854–1855	Lewis M. Dayton.
	1859–1863	Israel Dille.
New Concord	1849	Prof. S. G. Irvine.
New Lisbon	1857–1870	J. F. Benner.
New Westfield	1862, 1863	A. E. Jerome.
North Bass Island	1869–1873	Dr. George R. Morton.
North Bend	1868–1869	R. B. Warder.
North Fairfield	1867–1873	O. Burras.
Northwood	1852	Prof. J. R. W. Sloane.
Norton	1849	W. D. Watkins.
Norwalk	1854	G. A. Hyde.
	1861–1868	Rev. Alfred Newton.
Oberlin	1849–1850	Professors Fairchild and Dascomb.
	1851–1852, 1857	Prof. J. N. Allen.
	1855–1856	Prof. J. H. Fairchild.
	1860	Frederick Allen.
	1870–1873	L. Herrick.
Oxford, Miami University	1867	O. N. Stoddard.
	1868–1873	R. W. McFarland.
Pennsville	1871	J. P. King.
Perrysburgh	1854–1856, 1858	F. Hollenbeck.
	1857	F. and D. K. Hollenbeck.
Portsmouth	1855–1858	James H. Poe.
	1859–1863	Dr. D. B. Cotton.
	1863–1865	Lud. Engelbrecht.
Quaker Ridge	1870–1872	T. J. Ringman.
Republic	1851	Stephen S. Dorsey.
Richmond	1854–1855	Jacob N. Desellern.
Ripley	1857–1861	J. Ammen.
	1864–1867	Dr. G. Bamback.
	1867–1870	Mrs. M. M. Marsh.
Russell Station	1859–1860	J. W. Gamble.
Sago	1871	William Ballantine.
Salem	1870–1873	Rev. J. E. Pollock.
Sandusky	1859–1873	Thomas Niell.
Savannah	1854–1863	Dr. John Ingram.

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Name of station.	Period.	Name of observer.
Savannah	1871–1873	Dr. W. S. Shaw.
	1872–1873	Peter Bowman.
Saybrook	1862–1863	Rev. L. S. Atkins.
	1864–1866	James B. Fraser.
Seville	1861–1862	Rev. L. F. Ward.
Sharonville.	1859–1860	William F. Bowen.
Sidney	1857	Joseph Shaw.
Smithfield	1866	D. H. Tweedy.
Smithville	1864–1866	John H. Myers.
	1868–1870	William Hoover.
Steubenville	1849–1863	Roswell Marsh.
	1865–1871	J. B. Doyle.
Springfield	1859–1861	Samuel C. Frey.
	1870	Dr. G. P. Hachenberg.
Tiffin	1873	C. Hornung.
Toledo	1859	Sarah E. Bennett.
	1859	E. B. Raffensperger.
	1860–1870	Dr. J. B. Trembley.
Troy	1859–1863	Charles L. McClung.
Twinsburgh	1860	N. A. Chapman.
Unionville	1854–1857	Miss A. Cunningham.
	1858	Mrs. Ardelia C. King.
Urbana	1855–1873	Prof. M. G. Williams.
West Bedford	1856–1857	H. D. McCarty.
Welchfield	1857–1866	B. F. Abell.
Wellington	1863	Rev. L. F. Ward.
Westerville	1858-1862, 1868-1873	Prof. John Haywood.
	1863–1867	Prof. H. A. Thompson.
Western Star	1861	A. S. Stuver.
West Elkton	1872	Jesse Stubbs.
West Union	1860–1861	Rev. Wm. Lumsden.
Wooster	1849	Eugene Pardee.
	1864–1873	Martin Winger.
Williamsport	1867–1872	John R. Wilkinson.
Windham	1857–1859	Samuel W. Treat.
Yankeetown	1854	A. Jacque.
Yellow Springs	1868	W. A. Anthony.
Zanesfield	1854	John F. Lukins.
Zanesville	1856	L. M. Dayton.
	1859	Adam Peters.
	1853–1857	Dr. J. G. F. Holston.
Oregon.		
Albany	1865–1868	S. M. W. Hindman.
Astoria	1870–1873	Louis Wilson.
Auburn	1863–1865	R. B. Ironside.
	1864–1865	S. M. W. Hindman.
Corvallis	1866–1868	A. D. Barnard.
Eola	1870–1873	Thomas Pearce.
Fort Snyder	1858	James A. Snyder.
Fort Thompson	1857–1858	W. H. Wagner.
	1872	Chas. C. Coe.
Hood River	1872–1873	Thomas M. Whitcomb.
Oregon City	1851–1852	Geo. A. Atkinson.
Portland	1871–1873	Henry A. Oxer.
	1858–1859	Geo. H. Stebbins.
	1870	J. W. Gilliland.
	1871	James S. Reed.
Salem	1861	Thos. H. Crawford.
	1863–1865	P. L. Willis.
Pennsylvania.		
Abington	1864–1873	Rodman Sisson.
Allegheny City	1871–1873	B. Feicht.

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Name of station.	Period.	Name of observer.
Altoona	1859–1860	W. R. Boyers.
	1863	Thomas H. Savery.
Andersville	1854	R. Weiser.
Ashland	1870	Rev. W. E. Honeyman.
	1870–1873	A. W. Curtis.
Avondell	1868–1869	William E. Baker.
Beaver	1867–1872	Rev. R. T. Taylor.
Bedford	1852–1858	Samuel Brown.
	1859–1861	Rev. H. Heckerman.
Bellefonte	1858–1859	J. I. Burrell.
Bendersville	1859	Franklin W. Cook.
	1859–1860	T. E. Cook and Sons.
Berwick	1856-1861 1863-1865	John Eggert.
Bethlehem	1849	L. R. Huebener.
	1867	Nathan C. Tooker.
	1867–1868	Prof. A. M. Mayer.
Blairsville	1861–1865	W. R. Boyers.
Blooming Grove	1865–1873	John Grathwohl.
Brookville	1854	D. S. Deering.
Brownsville	1869–1873	Dr. J. Allen Hubbs.
Byberry	1852-1854, 1857-1858	John Cornly.
	1860–1861	John W. Saurman.
	1861–1867	Isaac C. Martindale.
Canonsburgh	1849	Prof. J. R. Williams.
	1849	F. L. Stewart.
	1855-1861, 1863-1873	Rev. Wm. Smith.
	1860	Charles Davis.
	1861–1863	Lyceum Jefferson College.
Carlisle	1849	Prof. S. F. Baird.
	1855–1859	Prof. W. C. Wilson.
	1868–1873	W. H. Cook.
Carpenter	1862	E. L. McNett.
Ceres	1849–1854	R. P. Stevens.
Chambersburgh	1858–1862	Wm. Heyser, jr.
Chromedale	1854–1857	Joseph Edwards.
	1858	Joseph Edwards and John H. Smedley.
Clarksburgh	1852	Barnet McElroy.
Connellsville	1849–1873	John Taylor.
Darby	1849–1852	John Jackson.
Dyberry	1865–1873	Theodore Day.
Easton	1849	A. R. McCoy.
	1851	Prof. J. H. Coffin.
	1851	E. L. Dodder.
	1857–1858	Selden J. Coffin.
	1859-1860	Selden J. Coffin and G. S. Houghton.
	1861	Geo. S. Houghton.
East Smithfield	1859	James E. Tracy.
Egypt	1870–1873	Edward Kohler.
Erie	1849	Benjamin Grant.
Ephratah	1865–1873	W. H. Spera.
Fallsington	1865–1873	Ebenezer Hance.
Franklin	1867–1873	Rev. M. A. Tolman.
	1872–1873	Joseph Bell.
Freeport	1849	Dr. A. Alter.
	1849–1851	Andrew Roulston.
	1854	A. D. Wier.
	1860	John H. Baird.
Fleming	1856–1867	Samuel Brugger.
Fountaindale	1868–1872	S. C. Walker.
Germantown	1859	S. Ebert.
	1862–1864	Thos. Meehan and J. Meehan.
	1859-1861, 1865-1873	Thomas Meehan.

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Name of station.	Period.	Name of observer.
Germantown	1869-1871	Ernest Turner.
Gettysburgh	1849-1860	Prof. M. Jacobs.
	1861	Rev. M. Jacobs and D. Eyster.
	1862-1865	Rev. M. Jacobs and H. E. Jacobs.
Grampian Hills	1864-1873	Elisha Fenton.
Greencastle	1870	Samuel N. Rhode.
Greensburgh	1871-1873	J. M. L. Stump.
	1873	G. B. Slattery.
	1872	W. D. Weaver.
Greenville	1871-1873	D. P. Packard.
Harrisburgh	1849	Dr. J. Heisely.
	1857-1864	W. O. Hickok.
	1860-1861	K. A. Martin.
	1869-1870	Dr. W. H. Egle.
	1871-1873	S. A. Black.
Hazleton	1870-1873	John Haworth.
Haverford	1853-1863	Dr. Paul Swift.
Hollidaysburgh	1853	J. R. Lowrie.
Honesdale	1852	M. H. Cobb.
Horsham	1864-1873	Miss Anna Spencer.
Huntingdon	1859	Dr. Wm. Brewster.
Ickesburgh	1867-1868	Wm. E. Baker.
Indiana	1849-1851	David Peelor.
	1858	W.D. Hildebrand and David Peelor.
Johnstown	1868-1871, 1873	David Peelor.
Kingsley's	1852	Francis Schreiner.
Lancaster	1849	F. A. Muhlenburg, jr.
	1849-1851	John Wise.
Latrobe	1860-1862	Prof. Rudolph Müller.
	1861	W. R. Boyers.
Lewisburgh	1855-1860, 1865-1873	Prof. C. S. James.
Lima	1849-1852	Messrs. Edwards and Miller.
	1853	Joseph Edwards.
	1859	John H. Smedley.
Linden	1858-1859	James Barrett.
Manchester	1849-1852	Corydon Marks.
Meadville	1849-1851	Prof. L. D. Williams.
	1854-1858	T. H. Thickstun.
Media	1860	Dr. Isaac N. Kerlin.
Moorhead	1863	R. L. Walker.
Morrisville	1849-1864	Ebenezer Hance.
	1859	Mahlon Moore.
Moss Grove	1853-1857	Francis Schreiner.
Mount Rock	1871-1873	Jacob Lefever.
Mount Joy	1857-1858	Mary E. Hoffer.
	1860-1873	Dr. Jacob R. Hoffer.
Murrysville	1857-1859	Thomas H. Stewart.
	1867-1868	F. L. Stewart.
Nazareth	1851	E. T. Kluge.
	1852	E. T. Kluge and E. Kummer.
	1855-1857	H. A. Brickenstein.
	1859-1860	J. C. Harvey.
	1861-	O. T. Huebner.
	1862	O. T. Huebner and L. E. Ricksecker
	1863-1866	L. E. Ricksecker.
New Castle	1866-1873	E. M. McConnell.
Norristown	1851-1863	Rev. J. G. Ralston.
Northeast	1867	John F. Milliken.
North Whitehall	1856-1868	Edward Kohler.
Oil City	1863-1864	James A. Weeks.
Oxford	1865	Dr. Henry Duffield.
Paradise	1854-1858	Jacob Frantz.
Parkerville	1859-1863, 1865	Fenelon Darlington.
Philadelphia	1849	United States navy-yard.

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Name of station.	Period.	Name of observer.
Philadelphia	1849	Lieut. Joseph Reed.
	1849–1852	Dr. Paul Swift.
	1849–1852	J. F. Coorlies.
	1852-1860, 1862-1873	Prof. J. A. Kirkpatrick.
	1857–1873	United States Naval Hospital.
	1860–1861	Dr. J. C. Martindale.
	1863	P. Friel.
	1864	Homer Eachers.
	1864–1865	Pennsylvania Hospital.
	1867	J. M. Ellis.
Phœnixville	1869	Isaac Z. Caffman.
Pittsburgh	1849–1851	Edward Fenderich.
	1849–1854	Dr. H. Smyser.
	1852–1858	W. W. Wilson.
	1857	William Martin.
	1855	John Hastings and William Martin.
	1858	William Martin and Dr. Alexander M. Speer.
	1859–1861	Dr. Alexander M. Speer.
	1863	Prof. Rudolph Müller.
	1870–1871	Charles Albree.
	1872–1873	George Albree.
Plymouth Meeting	1868–1872	Marcus H. Corson.
Pocopson	1853-1858, 1866-1873	Fenelon Darlington.
Pottsville	1854–1855	John Hughes.
	1855	Dr. A. Heger.
	1857	Rev. B. R. Smyser.
Pottsville	1858	D. Washburn.
Randolph	1851–1852, 1854–1856	Orrin T. Hobbs.
Reading	1857–1863, 1866–1873	John Heyl Raser.
	1858	Dr. J. B. Peale and Charles Hahn.
Rington	1872	N. S. Haines.
Salem	1869–1873	James D. Stacker.
Scranton	1858	Dr. A. P. Meybert.
Sewicklyville	1859–1860	John I. Travelli.
	1861	J. I. Travelli and G. H. Tracy.
	1862	George H. Tracy.
Shamokin	1856–1863	P. Friel.
Silver Spring	1863–1869	H. G. Bruckart.
Somerset	1852	Rev. David J. Eyler.
	1856	D. F. Chorpenning.
	1857–1861	George Moury.
Stevensville	1866–1867	J. Russell Dutton.
Saint Mary's	1849	William A. Stokes.
Sugar Grove	1849–1851	Lorin Blodget.
	1852–1854	W. O. Blodget.
Summit Hill	1852	M. Abbott.
Summitville	1852	Thomas Seabrook.
Susquehanna Depot	1863	H. H. Atwater.
Tarentum	1856–1860	John H. Baird.
	1871–1873	S. Cummings.
Tioga	1863–1873	E. T. Bentley.
Towanda	1861	S. J. Coffin, W. H. Dean, and I. H. Kingsbury.
Troy Hill	1855–1856	Victor Scriba.
Uniontown	1849	Freman Lewis.
Valley Forge	1849	C. P. Jones.
Warrior's Mark	1854	J. R. Lowrie.
Waynesborough	1853–1854	Rev. D. J. Eyler.
Wellsborough	1849	Henry W. Thorp.
Westchester	1858–1859	Samuel Alsop.
	1864–1865	Prof. A. G. Clark and T. H. Aldrich
	1868–1873	Dr. George Martin.
	1872	W. A. Jefferis.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
West St. Exp. Farm	1872	A. J. Hamilton.
Whitehall Station	1859–1860, 1868–1869	Edward Kohler.
Williamsport	1864, 1869–1871	H. C. Moyer.
	1873	Josiah Emery.
Worthington	1859–1862	Samuel Scott.
York Sulphur Springs	1871–1873	Dr. J. H. Marsden.
Youngsville	1853–1854	Dr. A. C. Blodget.
Rhode Island.		
East Greenwich	1855–1856	E. G. Arnold.
Newport	1854	Samuel Powel.
	1865–1870	W. H. Crandall.
	1870–1873	W. A. Barber.
North Scituate	1853–1854	Henry C. Sheldon.
Portsmouth	1854	George Manchester.
Providence	1849–1867	Prof. A. Caswell.
	1860–1864	H. C. Sheldon.
South Carolina.		
Aiken	1854–1856	H. W. Ravenel.
	1857–1861, 1867–1872	Rev. J. H. Cornish.
	1872–1873	Dr. W. H. Geddings.
Anderson	1868–1870	E. S. Earle.
Barrattsville	1849–1851	Dr. John P. Barratt.
Beaufort	1863–1865	Dr. M. M. Marsh and Mrs. Marsh.
Black Oak	1858–1861	Thomas P. Ravenel.
Bluffton	1870	S. Saint J. Guerard.
Camden	1851–1854	T. Carpenter.
	1869–1873	Colin Macrae.
Charleston	1849–1851, 1854–1857	Dr. J. A. Young.
	1851	Prof. L. R. Gibbes.
	1855–1857	Dr. Jos. Johnson.
	1857	Dr. J. L. Dawson.
	1858–1861	Dr. Jos. Johnson, J. L. Dawson, and G. S. Pelzer.
Columbia	1851	Col. W. Wallace.
	1856	F. H. Harleston.
	1856	Prof. J. B. White.
	1858	Capt. C. C. Tew.
	1859	Dr. E. H. Barton.
	1859	Superintendent Arsenal Academy.
Edisto Island	1855–1857	E. N. Fuller.
Fort Hill	1869–1870	R. A. Springs, jr.
Georgetown	1859–1861	Rev. Alexander Glennie.
Gowdeysville	1868–1873	Charles Petty.
Grahamville	1872	E. D. Pearsall.
Hacienda Saluda	1871–1873	Lardner Gibbon.
Hilton Head	1864	Maj. J. W. Abert, Capt. C. R. Suter.
	1865	Maj. C. R. Suter.
Mount Pleasant	1857	Dr. E. N. Fuller.
Orangeburgh	1849	Thomas A. Elliott.
	1849	Joseph T. Zealy.
Pomaria	1873	J. W. Folk.
	1872	D. Benjamin Busby.
Saint John's	1849–1852	H. W. Ravenel.
	1859–1860	Thomas P. Ravenel.
Waccamaw	1854–1858	Rev. Alexander Glennie.
Wilkinsville	1866–1867	Charles Petty.
Tennessee.		
Austin	1860–1861	Dr. S. K. Jennings.
	1868–1873	P. B. Calhoun.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Bethel Springs	1872–1873	Dr. S. K. Jennings.
	1872–1873	A. W. Stovall.
Castalian Springs	1872–1873	Dr. Thomas J. Kennedy.
Chattanooga	1864	Dr. G. H. Blaker.
Clarksville	1851–1873	Prof. W. M. Stewart.
Clearmont	1870–1873	T. P. Wright.
Cleveland	1873	H. Foster.
Dixon Springs	1852	Thomas L. Sawyer.
Dover	1849	B. F. Tavel.
Elizabethton	1868–1873	Charles H. Lewis.
Fayetteville	1849–1851	Dr. W. W. McNulty.
Franklin	1867	Dr. Jos. M. Parker.
Friendship	1854–1855	Dr. Robert T. Carter.
Greeneville	1866–1873	S. S. and W. S. Doak.
Jackson	1872	E. W. Amsden.
Knoxville	1851–1852	O. W. Morris.
	1853	Prof. George Cooke.
	1854	Prof. George Cooke and L. Griswold.
	1855–1856	T. L. Griswold.
	1860	Stephen C. Dodge.
	1869–1872	Prof. J. K. Payne.
La Grange	1859–1860	J. R. Blake.
	1870–1873	W. E. Franklin.
Lebanon	1851–1854	Prof. A. P. Stewart.
	1854	Prof. B. C. Jilson.
Lookout Mountain	1866–1867	Eward F. Williams.
	1867–1872	Rev. C. F. P. Bancroft.
McMinnville	1873	Miss Blanche Lewis.
Memphis	1849–1853	United States navy-yard.
	1851–1852	R. Harris.
	1857–1858	Dr. W. J. Tuck.
	1857	Dr. Daniel F. Wright.
	1859	Drs. W. Tuck and R. W. Mitchell.
Memphis	1860–1861	Dr. R. W. Mitchell.
	1867–1870	Edward Goldsmith.
Nashville	1849	Prof. James Hamilton.
	1849	William Rothrock.
	1854	James Higgins.
	1867–1868	Fred. H. French.
	1873	Charles A. Stillwell.
Pomona	1859–1861	J. W. Dodge & Son.
Rotherwood	1872–1873	Rev. C. Waterbury.
Smithville	1872–1873	P. C. Bluhm.
Trenton	1854	Professor Hamilton.
	1869–1873	William T. Grigsby.
University Place, Franklin County	1859–1861	Charles R. Barney.
Walnut Grove	1856–1857	James B. Bean.
Winchester	1859–1860	S. W. Houghton.
Texas.		
Aransas	1860	Frederick Kaler.
Austin	1852–1856	Dr. Samuel K. Jennings.
	1854	J. W. Glenn.
	1857	Dr. S. K. Jennings and J. Van Nostrand.
	1858–1864	Swante Palm.
	1858–1861, 1867–1873	J. Van Nostrand.
Bastrop	1859	J. D. Cunningham.
Bellona	1869–1870	Burke Combs.
Blue Branch	1870	W. H. Goode.
Bluff	1870–1873	Joseph Fietsam

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Name of station.	Period.	Name of observer.
Boerne	1872–1873	William Melchert.
Bonham	1859–1860	Prof. Solomon Sias.
Boston	1860–1861	G. Frees.
Boundary Survey	1859	John H. Clark.
Burkeville	1859–1861	Dr. N. P. West.
Cedar Grove Plantation	1867–1869	Hennell Stevens.
Chappell Hill	1866–1867	W. H. Gantt.
Clarksville	1870–1873	Rev. John Anderson.
Clear Lake	1871	George N. Leoni.
Clinton	1869–1872	Dr. A. C. White.
Columbus	1859	Dr. W. G. De Graffenried.
Cross-Roads	1859–1860	F. S. Wade.
Dallas	1859	John M. Crockett.
Deloraine	1871–1873	Samuel Davis.
Galveston	1867	Dr. C. H. Wilkinson, H. A. McComly, and others.
	1869	Dr. A. H. Beazley.
Geological Survey	1859	George G. Shumard.
Gilmer	1859–1861, 1867–1873	J. M. Glasco.
Goliad	1857–1858	John C. Brightman.
Gonzales	1859–1861	Melvin H. Allis.
Greenville	1859–1860	Dr. R. De Jernett.
Helena	1856–1857	John C. Brightman.
Highland	1872–1873	T. M. Scott.
Houston	1862–1865	Dr. A. M. Potter.
	1867–1872	Miss E. Baxter.
	1872–1873	Miss Jane Connell.
Huntsville	1849–1851	H. Yoakum.
	1852	J. H. Browne.
	1858–1860	T. Gibbs.
Kaufman	1859–1866	James T. Rayal.
	1866	James Brown.
Jefferson	1859	W. T. Epperson.
Larissa	1858–1860	F. L. Yoakum.
Lavaca	1869–1871	L. D. Heaton.
Lockhart	1869–1870, 1872	L. Woodruff.
Long Point	1867	M. Rutherford.
Mine Creek	1869–1870	F. S. Wade.
New Braunfels	1857	A. Forke and Otto Friedrich.
	1858–1860	Otto Friedrich.
New Ulm	1872–1873	C. Runge.
New Wied	1849–1854	T. C. Ervendberg.
	1855–1857	J. L. Forke.
Oakland	1870–1872	F. Simpson.
Palestine	1869–1870	N. S. Brooks.
Planaz	1869	John T. Coit.
Pope's Expedition	1855–1857	James M. Reade.
Port Lavaca	1859	James Gardiner.
Repose	1871–1872	Allen Martin.
Roundtop	1859–1861	Bruno Shuman.
San Antonio	1870–1873	Dr. Fred. Pettersen.
Sand Fly	1870–1873	F. S. Wade.
San Patricio	1859–1860	J. O. Gaffney.
Sisterdale	1859–1860	Ernest Kapp.
Springfield	1859	T. A. Turner.
Tarrant	1859–1860	Dr. B. S. D'Spain and J. M. Ewing.
Texana	1859	William Colman.
Turner's Point	1861	James T. Rayal.
Union Hill	1857–1861	Dr. William H. Gantt.
Waco	1867–1869	Dr. Edward Merrill.
Washington	1856–1860	B. H. Rucker.
Webberville	1859–1861	Prof. C. W. Yellowby.
Wheelock	1859–1861	F. Kellogg.
Woodborough	1859–1860	Dr. James E. Moke.

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Name of station.	Period.	Name of observer.
Utah.		
Camp Douglas	1871	A. C. Ford.
	1871	Charles Vieweg.
Coalville	1869–1872	Thomas Bullock.
Great Salt Lake City	1857	H. E. Phelps.
	1859–1861, 1863–1871	H. E. Phelps and W. W. Phelps.
	1872–1873	E. L. T. Harrison.
	1872–1873	Thomas Bullock.
Harrisburgh	1867–1873	James Lewis.
Heberville	1862–1864	Harrison Pearce.
Rockville	1866	Andrew L. Siber.
Saint George	1862–1864, 1869	Harrison Pearce.
	1865–1866	H. Pearce and G. A. Burgon.
	1870	C. Johnson.
Saint Mary's	1865	Thomas Bullock.
Vineland	1864	Andrew L. Siber.
Wanship	1866–1869	Thomas Bullock.
Washington	1860	Harrison Pearce.
Vermont.		
Barnet	1866–1867, 1869	Dr. B. F. Eaton.
Bradford	1856–1857	L. W. Bliss.
Brandon	1852–1864	D. Buckland.
	1864–1867, 1869	Harmon Buckland.
Brattleborough	1849–1851	Charles C. Frost.
Brookfield	1863	T. T. Pollard.
Burlington	1849–1854	Prof. Zadock Thompson.
	1857–1864	McK. Petty.
Calais	1861–1864	James K. Toby.
Castleton	1852–1854	D. Underwood.
	1869–1873	Rev. R. G. Williams.
Charlotte	1868–1873	M. E. Wing.
Craftsbury	1853–1854	Charles A. J. Marsh.
	1855–1867	James A. Paddock.
	1868–1873	Rev. Edward P. Wild.
East Bethel	1865	Charles L. Paine.
East Montpelier	1855	B. J. Wheeler.
Lunenburg	1859–1873	Hiram A. Cutting.
	1872–1873	Edward A. Cassino.
Middlebury	1849–1852	Prof. W. H. Parker.
	1865–1870	Harmon A. Sheldon.
Montpelier	1849–1851	D. P. Thompson.
	1863	M. M. Marsh.
Mount Anthony	1871	George W. Robinson.
Newport	1869–1870	E. M. Currier.
North Craftsbury	1867–1868	Rev. Edward P. Wild.
Norwich	1855–1859	A. Jackman.
	1871–1873	Samuel B. Phelps.
Panton	1869–1872	D. C. and Mrs. Barto.
Randolph	1849–1851	R. M. Manley.
	1866–1873	Charles S. Paine.
Rupert	1857–1863	Joseph Parker.
Rutland	1862–1864	S. O. Mead.
Saxe's Mills	1855	J. C. Baker.
Shelburne	1855–1857	George Bliss.
South Troy	1870–1872	James C. Kennedy.
Springfield	1860–1863	Rev. J. W. Chickering.
Saint Johnsbury	1853–1855	J. K. Colby and J. P. Fairbanks.
	1857–1861	Franklin Fairbanks.
Strafford	1873	H. F. J. Scribner.
West Fairlee	1858	L. W. Bliss.
Wilmington	1866–1867	Rev. John B. Perry.

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Name of station.	Period.	Name of observer.
Woodstock	1857–1858	Charles Marsh.
	1867	Lester A. Miller.
	1868–1873	H. Doton and L. A. Miller.
Virginia.		
Anna	1858–1859	Rev. C. B. McKee.
Alexandria	1849, 1853–1858	Benjamin Hallowell.
Ashland	1854, 1856–1857	Samuel Couch.
	1869	Prof. R. M. Smith.
Berryville	1855–1857	Miss E. Kounslar.
	1858	Dr. R. Kounslar.
Blacksburgh	1873	J. L. Hann.
Bridgeton	1868	C. R. Moore.
Bridgewater	1852–1854	Jed. Hotchkiss.
Buffalo	1851–1854	Prof. G. R. Rossiter.
	1855–1858	Samuel Couch.
	1858–1859	William R. Boyers.
Burning Springs	1868	Rev. Henry Bliven.
Cedar Hill	1871–1873	Capt. David B. Horne.
Cartersville	1872	Randolph Harrison.
Chambers' Valley	1873	J. B. Sunbach.
Charleston	1856–1857	Jas. E. Kendall.
Charlottesville	1849–1851	Charles J. Meriwether.
	1859–1861	J. Ralls Abell.
Christiansburgh	1851	William C. Hagan.
Cobham	1849–1851	Charles J. Meriwether.
Cobham Depot	1859–1861	George C. Dickinson.
Crichton's Store	1852–1861	R. F. Astrop.
Diamond Grove	1849–1851	R. F. Astrop.
Dover Mines	1873	Charles A. Harrington.
Fairfax	1870–1871	Miss L. R. Thrift.
Falmouth	1859–1861	Abraham Van Doren.
Fredericksburgh	1859–1861	Charles H. Roby.
	1849	B. R. Wellford.
Fork Union	1859–1861	Silas B. Jones.
Garysville	1856	Dr. T. A. Beckwith.
	1859	Julian C. Ruffin.
Gosport	1849	U. S. navy-yard
Hampton	1869–1873	James M. Sherman.
Hartwood	1858	Abraham Van Doren.
Heathsville	1849	J. C. Wills.
Hewlett's	1867	J. F. Adams.
Holliday's Cove	1858	B. D. Sanders.
Johnsontown	1868–1873	C. R. Moore.
Leesburgh	1849	N. F. D. Browne.
	1854	Samuel X. Jackson.
Lexington	1861	Wm. K. Park.
	1867–1870	W. H. Ruffner.
Linwood	1870–1871	Prof. J. L. Campbell.
	1871–1872	D. Payne.
Lloyd	1859	George W. Upshaw.
Longwood	1857	Thomas J. Wickline.
Lynchburgh	1854	A. Nettleton.
	1866–1873	Charles J. Meriwether.
Madison	1851–1852	Dr. A. M. Grinnan.
Markham Station	1870	L. E. Payne.
Meadow Dale	1857–1859	James Slaven.
Mechanicsville	1869–1873	William A. Martin.
Middlesex	1852	L. C. Breckenstein.
Montcalm	1854	Charles J. Meriwether.
Montrose	1856–1857	H. H. Fauntleroy.
Montross	1858–1859	Edward E. Spence.
Mossy Creek	1856–1858	Jed. Hotchkiss.

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Name of station.	Period.	Name of observer.
Mount Solon	1856–1856, 1867–1868	James T. Clarke.
	1868–1873	J. T. Clarke and Miss Bell Clarke.
Mustapha	1857–1858	James Fraser.
New England	1859–1861	James Fraser.
Norfolk	1868–1872	U. S. Naval Hospital.
Piedmont	1869–1872	Franklin Williams.
Portsmouth	1852–1860	N. B. Webster.
	1860–1861	Naval Hospital.
Powhatan Hill	1849–1873	Edward T. Tayloe.
Prince Edward	1849–1852	Prof. Francis J. Nuttaner.
Richmond	1849–1854	David Turner.
	1859–1861	Charles J. Meriwether.
	1860	John Appleyard.
	1872–1873	G. C. Vincent.
Rose Hill	1857–1858	George W. Upshaw.
Rougemont	1857–1858	George C. Dickinson.
Ruthven	1856–1858	Julian C. Ruffin.
Salem	1857–1858	J. Carson Wells.
Smithfield	1856–1861	John R. Purdie.
Snowville	1867–1870	J. W. Stalnaker.
	1872–1873	E. D. Stenker.
Staunton	1849	J. B. Imboden.
	1868–1872	J. C. Covell.
Stribling Springs	1859	Jedediah Hotchkiss.
Surry	1867–1871	Benjamin W. Jones.
The Plains	1859–1860	John Pickett.
Vienna	1869–1872	H. C. Williams.
	1870	J. B. Bowman.
	1870–1873	G. A. Bowman.
	1871	Randolph Robey.
Waterford	1871–1872	Mrs. S. E. Chamberlain.
Winchester	1852–1861, 1859–1861	J. W. Marvin.
Woodlawn	1870–1873	Chalkley Gillingham.
Wytheville	1861	W. D. Roedel.
	1865–1866, 1872–1873	Howard Shriver.
	1868–1873	Rev. James A. Brown.
Zinn Station	1869–1871	Robert Binford.
Washington Territory.		
Cathlamet	1870–1873	Charles McCall.
Fort Colville	1860–1861	Captain Hague.
Fort Steilacoom	1863–1864	Dr. David Walker.
Fort Vancouver	1859	Dr. Barnes.
Neeah Bay	1862–1866	James G. Swan.
	1867	Alexander Sampson.
Port Angelos	1869–1872	Alexander M. Sampson.
Port Townsend	1867–1868	S. S. Bulkley.
Seattle	1870	Mr. and Mrs. J. E. Whitworth.
Union Ridge	1869–1870	A. H. Simmons.
Walla Walla	1871–1872	Thomas M. Whitcomb.
West Virginia.		
Ashland	1865–1872	Charles L. Roffe.
Burning Springs	1867–1868	Robert H. Bliven.
Capon Bridge	1857	Dr. J. J. Offutt.
Crackwhip	1856–1857	D. H. Ellis.
Grafton	1867–1868	Dr. W. H. Sharp.
Hampshire County	1868	S. J. Stumps.
Harper's Ferry	1860	L. J. Bell.
Huntersville	1851–1856	William Sheen.
Huttonsville	1869	Jacob I. Hill.
Kanawha	1856–1857	David L. Ruffner.

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Name of station.	Period.	Name of observer.
Kanawha	1858, 1860–1861	James E. Kendall.
Kanawha Salines	1858–1859	W. C. Reynolds.
Lewisburgh	1851–1852	Dr. William N. Patton.
	1853–1857	Dr. Thomas Patton.
	1858	Thos. Patton and J. W. Stalnaker.
	1859–1861	J. W. Stalnaker.
Morgantown	1872–1873	Prof. S. G. Stevens and Miss M. T. Stevens.
New Creek Station	1856–1865	Hendricks Clark.
Point Pleasant	1858	W. R. Boyers.
Romney	1852	Marshall McDonald.
	1866–1870	W. H. McDowell.
Sistersville	1857–1858	Enoch D. Johnson.
Wardensville	1855, 1859–1861	D. H. Ellis.
Wellsburgh	1859–1860	B. D. Sanders.
Weston	1868, 1870–1871, 1873	Benjamin Owen.
	1869	H. P. Camden.
	1873	E. Ralston.
West Union	1855–1856	W. C. Quincy.
Wheeling	1859–1860	George P. Lockwood.
Wirt	1856–1858	Josiah W. Hoff.
Wisconsin.		
Appleton	1856–1861	Prof. R. Z. Mason.
	1867	John Hicks.
	1867	Dr. M. J. E. Hurlburt.
	1867–1871	Prof. J. C. Foye.
Ashland	1862	Edwin Ellis.
Audubon	1873	A. T. Dearborn.
Aztalan	1849–1852	James C. Brayton,
Baraboo	1849–1852	Dr. B. F. Mills.
	1864–1872	M. C. Waite.
Bay City	1857–1858	Edwin Ellis.
Bayfield	1858–1859	Harvey J. Nourse.
	1867–1873	Andrew Tate.
Bellefontaine	1851–1854	Thomas Gay.
Beloit	1849–1854	Prof. S. P. Lathrop.
	1854	J. McQuigg and W. Porter.
	1855–1860	Prof. William Porter.
	1861, 1862	Prof. Henry S. Kelsey.
	1863–1867	Henry D. Porter.
	1871–1873	Beloit College.
Black River Falls	1859	Emil Hauser.
Brighton	1862–1863	George Mathews.
Burlington	1859	D. Matthews.
	1860	D. and G. Matthews.
	1861	George Matthews.
Caldwell Prairie	1860–1861	S. Armstrong.
Cascade Valley	1856	Samuel R. Seibert.
Ceresco	1854–1855	Miss M. E. Baker.
Dartford	1861–1862	M. H. Towers.
Delafield	1859–1860	Prof. A. W. Clark.
	1861–1863	Charles W. Kelly.
Delavan	1864–1867	Levens Eddy.
	1873	E. N. Lee.
Edgerton	1867–1873	Henry J. Shintz.
Elkhorn	1873	Geo. W. Hodges.
Emerald Grove	1849–1852	Orrin Dinsmore.
Embarrass	1864, 1866–1873	J. Everett Breed.
Falls of St. Croix	1857	M. T. W. Chandler.
	1858	Wm. M. Blanding.
Galesville	1867–1868	Wm. Gale.
Geneva	1863–1873	W. H. Whiting.

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Name of station.	Period.	Name of observer.
Green Bay	1859	Col. D. Underwood.
	1864–1865	Frederick Deckner.
Green Lake	1851–1852	C. F. Pomeroy.
Hartford	1859–1862	Judge Hopewell Cox.
Hingham	1867–1873	John De Lyser.
Hudson	1854	G. F. Livingston.
Irish Settlement	1870–1872	John O'Donoghoe.
Janesville	1853–1858	J. F. Willard.
	1859	Geo. J. Kellogg.
	1860–1861	Dr. Clark G. Pease.
	1862	Daniel Strunk.
Kenosha	1851–1852, 1857–1863	Rev. John Gridley.
Kilbourn City	1860–1862	James H. Bell.
Lake Mills	1859–1862	Isaac Atwood.
Lebanon	1864	J. C. Hicks.
LeRoy	1872–1873	Elliott H. Benton.
Lind	1858	R. H. Struthers.
Madison	1853	Prof. S. H. Carpenter.
	1854	S. H. Carpenter and J. W. Sterling.
	1856–1858	Dr. A. Schue.
	1856–1859, 1863–1865	Prof. J. W. Sterling.
	1860	J. Jennings.
	1860	Prof. J. W. Sterling and S. P. Clarke.
	1861–1862	Prof. J. W. Sterling and W. Fellows.
	1869–1873	W. W. Daniels.
Manitowoc	1857–1873	Jacob Lüps.
Menasha	1857–1858	Col. D. Underwood.
Milton	1872–1873	Evan L. Davis.
Milwaukee	1849–1852, 1854, 1857–1871	I. A. Lapham.
	1854–1867	Dr. Carl Winkler.
	1855–1859	F. C. Pomeroy.
	1859–1861	Prof. E. P. Larkin.
Mosinee	1859	J. S. Pashley.
Mount Morris	1858	Wm. F. Horsford.
New Holstein	1865	Ferdinand Hachez.
New Lisbon	1867–1873	John L. Dunegan.
New London	1857–1858	J. Everett Breed.
Norway	1855–1857	John E. Himoe.
Odanah	1863–1866	Dr. Edwin Ellis.
Otsego	1859–1860	L. H. Doyle.
Pardeeville	1859–1860	S. Armstrong.
Platteville	1851–1859	Dr. J. L. Pickard.
	1859–1860	A. K. Johnson.
Plymouth	1865–1870	G. Moeller.
Prescott	1857	Spencer L. Hillier.
Racine	1856	Rev. Roswell Park.
	1856–1858	W. J. Durham.
	1860–1861	Hiland W. Phelps.
Ripon	1865–1866	Prof. W. H. Ward.
Rocky Run	1859–1873	W. W. Curtis.
Rolla	1868	Homer Ruggles.
Rural	1860–1861	R. H. Struthers.
Southport	1849	Rev. John Gridley.
Sturgeon Bay	1870–1871	Rufus M. Wright.
	1872–1873	Mrs. C. C. Pinney.
Summit	1851–1854	Edward S. Spencer.
Superior	1855	Wm. H. Newton and L. Washington.
	1856	L. & R. Washington and C. Loring, jr.
	1859–1863	Wm. Mann.
	1859–1863	G. R. Stuntz and E. H. Bly.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
Walworth	1873	N. J. Read.
Waterford	1863	S. Armstrong.
Watertown	1852	William Ayres.
Waukesha	1857	Prof. S. A. Bean and Dr. L. C. Slye
	1855–1856, 1858–1859	Prof. S. A. Bean.
Waupaca	1856–1865	J. Everett Breed.
	1863–1873	M. C. Mead.
	1867	C. D. Webster.
Wausau	1859–1860	Dr. W. A. Gordon.
Wautoma	1870–1873	Jonathan Spaulding.
Weyauwega	1860–1861	Melzar Parker.
	1861–1864	William Woods.
	1866	John C. Hicks.
	1866	Dr. Jas. Matthews.
	1873	H. H. Nicholson.
Whittlesey	1859–1860	Dr. Edwin Ellis.
Wien	1873	Jacob Duerstein.
Wyoming Territory.		
Atlantic	1872	George H. Lewis.
Laramie City	1871	D. J. Pierce.
CENTRAL AMERICA.		
COSTA RICA.		
Limon	1865–1866	Felipe Valentin.
San José	1862–1866	C. N. Riotte.
	1866–1867	Dr. A. Von Frantzius.
	1867–1868	Oficina Central di Estadistica.
GUATEMALA.		
Guatemala	1858–1862	Antonio Canudas.
HONDURAS.		
Belize	1862–1868	S. Cockburn.
Truxillo	1854	E. Purdot.
NEW GRANADA.		
Aspinwall	1857–1865	Dr. W. T. White.
	1865–1866, 1868	Dr. J. P. Kluge.
	1867	Drs. J. P. Kluge, G. V. Rucker.
NICARAGUA.		
....	1855	J. Moses.
MEXICO.		
Chinamaca	1859	Charles Laszlo.
Cordova	1858–1860	J. A. Hieto.
Frontera Tabasco	1865	Charles Laszlo.
Mexico	1855–1856	Prof. L. C. Ervendberg.
Minititlan	1858–1860	Charles Laszlo.
Mirador	1858–1871	Dr. Charles Sartorius.
San Juan Bautiste	1861–1864	Charles Laszlo.
Tuspan	1867	Benjamin Crowther.
Vera Cruz	1859	Herman Berendt.

Monthly meteorological reports preserved in the Smithsonian Institution—Continued.

Name of station.	Period.	Name of observer.
ANTILLES.		
Sombrero Island	1863–1864	Alexis Julien.
	1865	Milton Brayton.
BAHAMAS.		
Turk's Island	1859	J. B. Hayne.
	1860	J. C. Crisson, Capt. W. Hamilton.
	1861	A. G. Carothers.
	1862–1865	United States consul.
	1868	J. C. Crisson.
Turk's Island, Salt Cay	1861	S. G. Garland.
Nassau, N. P	1858–1859	A. M. Smith.
BERMUDA.		
Hamilton	1852	Captain Alexander.
	1857	Royal Gazette.
Shelby Bay	1857	James B. Arnold.
St. George's	1858	James Crawford.
	1858–1868	Center Signal Station.
Ireland Island	1859	John G. Calder.
JAMAICA.		
Upper Park Camp	1855–1856	James G. Sawkins.
	1855	Col. W. B. Marlow.
PORTO RICO.		
Est. San Ysidro	1868	George Latimer.
SAN SALVADOR.		
La Union	1858	Dr. Charles Dorat.
ST. DOMINGO.		
....	1860	Jonathan Elliott.
SOUTH AMERICA.		
DUTCH GUIANA.		
Surinam	1860–1873	C. J. Hering.
ASIA.		
TURKEY.		
Bitlis	1869–1870	Rev. George C. Knapp.
JAPAN.		
Yokohama	1873	Naval Hospital.
MISCELLANEOUS.		
	1872–1873	United States steamships Alaska Narragansett, Shenandoah, Lancaster, Monongahela.

CLASSIFIED LIST OF METEOROLOGICAL PUBLICATIONS, AND METEOROLOGICAL ARTICLES IN PERIODICALS, RECEIVED BY THE SMITHSONIAN INSTITUTION IN 1873, AND DEPOSITED IN THE LIBRARY OF CONGRESS.

AURORAS.

Die Nordlichter verursacht durch die Strömungen im Luftmeere an den Beobachtungen nachgewiesen. Professor Prestel. (Zeitschrift der österreichischen Gesellschaft für Meteorologie, vii, No. 10.)

Le aurore boreali e i fenomeni meteorologici di Ottobre 1870.

Note à propos d'une aurore boréale observée à Orléans le 4 février 1872, (Mémoires de la Société d'agriculture, etc., d'Orléans, tome xv, Nos. 1–2.)

EARTHQUAKES.

Il tremuoto delle notte da 12 a 13 Dicembre 1869. (Rendiconti della Società dei naturalisti di Modena, No. 1.)

Note sur le tremblement de terre ressenti le 22 octobre 1873, dans la Prusse rhénane et en Belgique. M. Albert Lancaster.

Notes sur les tremblements de terre en 1869, avec suppléments pour les. années antérieures de 1843 à 1867. (Mémoires couronnées et autres mémoires publiées par l'Académie royale des sciences, etc., de Belgique, tome xxii.)

Sui terremoti recenti nelli Romagne. Dottore Jacops Michez. (Effemeridi della Società de letture e conversazioni scientifiche, anno 2, vol. 1, fascioli 1–2.)

ELECTRICITY.

Resultate delle osservazioni sull' elettricismo atmosferico, istitute nel Reale osservatorio di Modena. D. Ragona.

FORESTS.

Der Einfluss des Waldes auf das Klima. Th. Hartung, 1871.

GENERAL METEOROLOGY.

Contributions to our knowledge of the antarctic regions. London, 1873.

La meteorografia del globo studiata a diverse altitudine da terra. F. Zantedeschi. (Commentari dell' Ataneo di Brescia per gli anni 1868–69.)

L'umidita. Lettura del Prof. D. Ragona. Milano, 1873.

Osservazioni su la evaporazione, del Prof. D. Ragona.

Papers on the cause of rain, storms, the aurora, and terrestrial magnetism. G. A. Rowell. London, 1871.

Sopra alcuni fenomeni di fisica terrestre in relazione con alcuni fenome-

ni di fisica solare. A. Palagi. (Memoria dell' Accademia delle scienze dell' Istituto di Bologne, serie 3, tomo 2, fasciolo 2.)

Suggestions on a uniform system of meteorological observations. (Royal Dutch Meteorological Institute, Utrecht, 1872.)

Sur un système météorographique universel. M. Van Rysselberghe. (Bulletin de l'Académie des sciences, des lettres et des beaux arts de Belgique, 42e année, 2e série, tome 36, Nos. 9–10.)

Rapports de MM. Gloesener et Liagre sur la notice de M. Van Rysselberghe, concernant un système météorographique universel. (Bulletin de l'Académie royale des sciences, etc., de Belgique, 42e année, 2e série, tome 36, No. 8.)

Ueber die Ursachen des eisfreien Meeres in den Nordpolargegenden. F. V. Kuhn. (Zeitschrift der österreichischen Gesellschaft für Meteorologie, vol. 7, No. 10.)

INSTRUMENTS.

Descrizione dell' igrotermografo del Reale osservatorio di Modena del Prof. D. Ragona.

Descrizione della nuova finestra meteorologica del Reale osservatorio di Modena del Prof. D. Ragona.

Descrizione del barometro registratore del Reale osservatorio di Modena del Prof. D. Ragona.

Esposizione e discussione dei resultate del barometro registratore del Reale osservatorio di Modena per l'anno 1867, del Prof. D. Ragona.

MAGNETISM.

Contributions to terrestrial magnetism, No. 13. Gen. Sir Edward Sabine.

Magnetiska Observationer under Svenska Polarexpeditionen, Ar 1868, af Karl Selim Lehmstrom. Stockholm, 1870.

Sulla possibile connessione fra le eclisse di sole ed il magnetismo terrestre. Memoria del Prof. Francesco Denza Barnabita. Roma, 1873.

METEORITES.

Bolide observé à Bruxelles le 21 juillet 1873. (Bulletin de l'Académie royale des sciences, etc., de Belgique, 42e année, 2e série, tome 36, No. 8.)

Considerazioni sul radiante della pioggia meteorica del 27 Novembre 1872. Nota del Prof. Domenico Ragona. Firenze, 1873.

Les étoiles filantes, les bolides. (De l'astronomie dans l'Académie royale de Belgique, rapport séculaire, 1772–1872.)

Meteorsfallet vid Hessle den 1sta Januari 1869, af A. E. Nordenskiöld.

November meteors, 1869. Charles Meldrum, Mauritius.

Sopra una probabile connessione fra le eclisse di sole ed il magnetismo terrestre. J. Michez. (Memoria dell' Accademia delle scienze dell' Istituto di Bologna, serie 3, tomo 2, fasciolo 1.)

Stelle meteoriche di Agosto 1867, osservati nel Reale osservatorio di Modena. D. Ragona.

Sulla relazione fra le comete, le stelle cadenti, ed meteorite. Schiaparelli. (Memoria del Reale istituto lombardo di scienze e lettere, vol. 12, 3 della serie 3, fasciolo 3.)

Sur les étoiles filantes de la période de novembre 1871, et sur les aurores boréales des 9 et 10 du même mois. Note par M. Ad. Quetelet.

Sur les étoiles filantes du mois d'août 1873, par M. Ad. Quetelet. (Bulletin de l'Académie des sciences, des lettres et des beaux arts de Belgique, 42e année, 2è série, tome 36, Nos. 9–10.)

LOCAL METEOROLOGY.

AFRICA.

Egypt.

Statistique de l'Égypte, année 1873.

Mauritius.

Monthly notices of the Meteorological Society.

Rain-fall of Mauritius, by Charles Meldrum.

Port Louis.—Results of observations at the observatory, 1870.

ASIA.

India.

Report on meteorological observations in the northwestern provinces of India, by Murray Thompson.

Bengal.—Meteorological observations. (Proceedings of the Asiatic Society of Bengal, December, 1872, and January to April, 1873.)

Report of the meteorological reporter to the government of Bengal for the year 1867–68, with a meteorological abstract for the year 1867. Calcutta, 1868.

Report of the meteorological reporter to the government of Bengal for 1870. Henry T. Blanford. Calcutta, 1872.

Report of the meteorological reporter to the government of Bengal. Meteorological abstract for 1872. By Henry Blanford. Calcutta, 1873.

Bombay.—Magnetical and meteorological observations at the government observatory from 1865 to 1870.

Water-supply of Bombay. (Professional papers on Indian engineering, 2d series, vol. 2, No. 9.)

Oudh.—Report on meteorology in the province of Oudh, for 1871–72.

Punjab.—Report on the meteorology of the Punjab, for the year 1871, by A. Neil. Lahore, 1872.

Japan.

Meteorology of Japan. Dr. Thomas Antisell. 1872.

AUSTRALIA.

New South Wales.

Results of meteorological observations made in New South Wales in 1872 by H. C. Russell. Sydney, 1873.

Meteorological observations made at the government observatory, Sydney, in 1871–73, under the direction of H. C. Russell.

Results of meteorological observations in 1871. H. C. Russell. Sydney, 1872.

Brisbane.—Meteorological summaries from about fifty stations. E. McDonnell.

EUROPE.

Austria.

Zeitschrift der österreichischen Gesellschaft für Meteorologie. Dr. C. Jelinek und C. Hahn. Vol. 7. Wien.

Jahrbücher der kaiserlich-königlichen Centralanstalt für Meteorologie und Erdmagnetismus, von Dr. C. Jelinek und Carl Fritsch. Wien, 1873.

Uebersicht der phanologischen Beobachtungen im Jahre 1870.

Cracow.—Meteorologische Beobachtungen, angestellt an der kaiserlich-königlichen Sternwarte in Krakau im Jahre 1872.

Pola.—Kaiserlich-königliches hydrografisches Amt. Witterungsübersicht, 1872.

Prague.—Magnetische und meteorologische Beobachtungen auf der kaiserlich-königlichen Sternwarte zu Prag in 1871.

Belgium.

Observations des phénomènes périodiques pendant l'année 1869. (Mémoires de l'Académie royale des sciences de Belgique, tome 39.)

Observations des phénomènes périodiques pendant l'année 1870. (Extrait du tome 39 des Mémoires de l'Académie royale de Belgique.)

Note sur les orages qui ont sévi à Aartselaer le 23, le 26, et le 29 juillet 1873. (Bulletin de l'Académie royale des sciences, etc., de Belgique, 42e année, 2e série, tome 36, No. 8.)

Antwerp.—Mesures d'altitudes barométriques prisés à la tour de la cathédrale d Anvers, sous l'influence de vents de vitesses et de directions différentes. (Bulletin de l'Académie royale des sciences, etc., de Belgique, 42e année, 2e série, tome 35, No. 6.)

Brussels.—Détermination de la déclinaison et de l'inclinaison magnétique à Bruxelles en 1873. (Bulletin de l'Académie royale des sciences, etc., de Belgique, 42e année, 2e série, tome 36, No. 8.)

Mechlin.—Observations faites à Malines par M. Doumet. (Annales de la Société d'horticulture de l'Allier.)

Denmark.

Monthly meteorological records for Shagen, Hammershut, and other places.

England.

Journal of the Royal Agricultural Society of England. 2d series, vol. 8, part 1.

Meteorology of England during the quarter ending December 31, 1871. James Glaisher.

On the rain-fall of 1872. James Tait. (Proceedings of the Berwickshire Naturalists' Club, vol. 6, No. 7.)

Quarterly Journals of the Meteorological Society. Edited by James Glaisher.

Quarterly Journal of the Meteorological Society, vol. 1, 1873.

Quarterly weather-report of the meteorological office, part 4, October to December, 1870.

Quarterly weather-reports of the meteorological office, July to September, 1871, and July to September, 1872.

Report of the meteorological committee of the Royal Society for the year ending December 31, 1872.

Symons' Monthly Meteorological Magazine, March, 1873. London.

Weather-reports, July 1 to December 31, 1872. Meteorological office.

Weather-reports, January 1 to December 31, 1871. Meteorological office.

Cornwall.—Meteorology of West Cornwall. (Fortieth annual report of the Royal Cornwall Polytechnic Society.)

Greenwich.—Results of the magnetical and meteorological observations made at the Royal Observatory, 1870.

Greenwich magnetical and meteorological observations, 1871.

Stonyhurst.—Results of meteorological and magnetical observations, 1871.

France.

Annuaires de la Société météorologique de France, 1869–71.

Annuaire de la Société météorologique de France, tome 18, 1870.

Sur les grands crues survenues dans le bassin de la Loire pendant l'hiver 1872–73. (Annales des ponts et chaussées, avril 1873.)

Le Mans.—Table résumé des observations faites au Mans par M. D. Bonhomet pendant le 3e et 4e trimestres de 1871. (Bulletin de la Société d'agriculture, sciences et arts de la Sarthe, 11e série, tome 13.) Le Mans, 1872.

Lyons.—Observations météorologiques faites à l'observatoire de Lyon du 1er décembre 1869 au 1er décembre 1871. (Mémoires de l'Académie des sciences de Lyon, tome 19.)

Montsouris.—Bulletin de l'Observatoire météorologique central, 1870–71.

Bulletin de l'Observatoire météorologique central de Montsouris, janvier, février, 1872.

Supplément, juillet à septembre 1870.

Supplément, 1871, additions et corrections.

Paris.—Atlas annuel de l'observatoire de Paris, 1872.

Bulletin international, juin 1873.

Bulletin mensuel de l'observatoire de Paris, 1872.

Toulouse.—Résumé annuel des observations météorologiques faites à l'observatoire de Toulouse pendant les années 1868–70, par M. Daguin. (Mémoires de l'Académie des sciences, inscriptions et belles-lettres de Toulouse, 7e série, tome 3.)

Tableaux mensuels de principales observations météorologiques faites à l'observatoire de Toulouse, pour les quatre dernier mois de l'année météorologique 1869–70, par M. Daguin. (Mémoires de l'Académie des sciences, inscriptions et belles-lettres de Toulouse, 7e série, tome 3.)

Tours.—Observations météorologiques du mois d'octobre. Observations météorologiques du mois de novembre. Résumé météorologique de l'année 1870–71. M. de Tastes. (Annales de la Société d'agriculture, sciences, arts et belles-lettres, 102e année, tome 1, No. 5.) Tours, 1871.

Hanover.

Der Boden, das Klima und die Witterung von Ostfriesland, von M. A. F. Prestel. Emden, 1872.

Holland.

Résumé des observations météorologiques faites à Luxembourg en 1870. M. F. Reuter. (Publications de l'Institut royal grand ducal de Luxembourg, tome 12, 1872.)

Hungary.

Magnetische Ortsbestimmungen im Königreiche Ungarn. Wien, 1871.

Ireland.

A comparative view of meteorological observations made in Ireland since 1788. Richard Kirwan. Dublin.

Italy.

Bolletino meteorologico. (Giornali agrario italiano.)

Sul clima d'Italia. Luigi Rolla. (Commentari dell' Ateneo di Brescia per gli anni 1868–69.)

Brescia.—Osservazioni meteorologiche dell' anni 1868–69. (Commentari dell' Ataneo di Brescia per gli anni 1868–69.)

Milan.—Rigoledo nel 1871. Note statistiche d'idroterapia ed climatologia del dottore Carlo Zucchi.

Sul grande commovimento atmosferico avvenuti il 1° Agosto 1872, nella bassa Lombardia e nella Lomellina. Annotazione di Giovanni Celosia, 1873. (Bolletino del Reale osservatorio di Brera in Milano.)

Modena.—Le stazioni pluviometriche della provincia di Modena.

L'umidita. Lettura del Prof. D. Ragona, direttore del Reale osservatorio di Modena.

Résumé des observations sur la météorologie faites à l'Observatoire royale de Modena, par M. le professeur D. Ragona, année 1867.

Naples.—Specola reale di Napoli. Osservazioni meteoriche del Dicembre 1872, fatte dal astronomo professore F. Brioschi.

Turin.—Supplemento al Bolletino annuale 1870 dell' osservatorio astronomico dell' Università di Torino.

Bolletino meteorologico ed astronomico del Reale osservatorio dell' Università di Torino, 1871.

Udine.—Osservazioni meteorologiche istituto in Udine nell' anno 1870. (Annali scientifici del Reale istituto tecnico di Udine, 1871.)

Venice.—Bolletino meteorologico con annotazione statistiche e mediche per Gennaio e Febbraio 1872. (Atti del Reale istituto veneto di scienze, lettere ed arti dal Novembre 1872 all' Ottobre 1873, tomo 2o, serie 4a, dispensa 2a.)

Bolletino meteorologico con osservazione statistiche e mediche pei mesi di Maggio e Giugno 1872. (Atti del Reale istituto veneto di scienze ed arti, tomo 2o, serie 4a, dispensa 5a.)

Prussia.

Meteorologische Beobachtungen aus Mähren und Schlesien in 1870. (Verhandlungen des naturforschenden Vereines in Brunn, 9ter Band.)

Frankfort.—Zwölf Monatstabellen. Hauptergebnisse, Grundwasserbeobachtungen, Vegetationszeiten, Sternschnuppenbeobachtungen, vom Jahre 1871 und 1872. Graphische Darstellung der Witterungs- und Grundwasserbeobachtungen. (Jahresbericht des physikalis chen Vereins zu Frankfurt am Main für das Rechnungsjahr 1871–72.)

Russia.

Repertorium für Meteorologie. Dr. H. Wild. St. Petersburg, 1872.

Dorpat.—Meteorologische Beobachtungen angestellt in Dorpat im Jahre 1866. Doktor Arthur von Oettingen.

The same for 1870.

Meteorologische Beobachtungen in Dorpat, 1871.

Saxony.

Monatliche Berichte über die Resultate aus den meteorologischen Beobachtungen in Sachsen in 1871. Dresden, 1872.

Resultate aus den meteorologischen Beobachtungen angestellt an 24 sächsischen Stationen im Jahre 1870, von Dr. C. Bruhns. Dresden und Leipzig, 1873.

Chemnitz.—Witterungsbeobachtungen aus den Jahren 1870–72. (Vierter Bericht der naturwissenschaftlichen Gesellschaft zu Chemnitz, 1873.)

Scotland.

Journal of the Scottish Meteorological Society, January to April, 1872, with tables for the half-year ending December 31, 1871.

Journal of the Scottish Meteorological Society, with tables for the half-year ending December 31, 1872.

Quarterly reports of the Meteorological Society of Scotland, 1859–'62.

Sweden.

Meteorologiska Jaktagelser i Sverige, utgifna af kongl. svenska Vetenscaps-Akademien, vols. 9–11.

Upsal.—Bulletin météorologique mensuel de l'observatoire de l'université d'Upsal, vols 1–3. Dr. R. Rulenson.

Switzerland.

Monthly meteorological observations at Neuchatel, Chaumont, and Affoltern. (Bulletin de la Société des sciences naturelles.)

Schweizerische meteorologische Beobachtungen, December 1871 und Januar und Februar 1872.

Schweizerische meteorologische Beobachtungen, herausgegeben von der meteorologischen Centralanstalt der schweizerischen naturforschenden Gesellschaft. Prof. Dr. Rudolf Wolf. 7ter Jahrgang. Zürich, 1870.

Geneva.—Résumé météorologique de l'année 1871, pour Genève et le Grand St. Bernard, par E. Plantamour.

Lausanne.—Bulletin mensuel des observations météorologiques de Lausanne, par J. Marguet, 1871. (Bulletin de la Société vaudoise des sciences naturelles, vol. 11, No. 66, 1871.)

Würtemberg.

Würtembergische Jahrbücher für Statistik und Landeskunde. Stuttgart.

NORTH AMERICA.

Canada.

Toronto.—Monthly meteorological register and remarks. (Canadian Journal of Science, Literature and History.)

United States.

Meteorological observations at lake stations. (Annual report of Chief of Engineers, Washington.)

North Carolina.—Western North Carolina, its agricultural resources, climate, &c. E. J. Aston. Milwaukee, 1870.

SOUTH AMERICA.

Notes on the climate of the Maranon. Francis L. Galt. (Proceedings of the Royal Geographical Society, vol. 17, No. 2.)

Chili.—Resumen mensual de las observaciones meteorologicas efectuados en el año de 1870.

Venezuela, Caracas.—Observaciones meteorologicas en Caracas, 1868–69.

WEST INDIES.

Cuba.—Memoria de la marcha regular, ó periodica é regular, del barometro desde 1858 á 1871 inc., por el R. P. H. Viñes, director.

Observaciones magneticas y meteorologicas del Real colegio de Belen, 1870–71.

Observaciones magneticas y meteorologicas per diferentes horas del dia. (Anales de la Academia de ciencias, medicas, fisicas y naturales de la Habana.)

OCEAN-CURRENTS.

The sea temperature and currents of the 10° square of the Atlantic between the equator and 10° north and 20° to 30° west. (Lecture by W. E. Nicholson, in Journal of Royal Service Institution, No. 72.)

OZONE.

Sui coefficienti ozonometrici dell' umidita e della temperatura. Nota del Professore Ragona.

RAIN.

Rain-fall and evaporation in its relation to water-supply. Alexander Leslie. (Transactions of the Royal Society of Arts, vol. 8, p. 3.)

Sulla pioggie di Ottobre 1872. Nota del Prof. Domenico Ragona, direttore del Regio osservatorio di Modena.

TEMPERATURE.

Coefficiente termometrico per ricovare la temperatura media diurna dar termometri a massima e minima. Calcolati per ogni giorno dell' anno dal Prof. Domenico Ragona, direttore del Reale osservatorio di Modena.

WIND.

Air-currents in the Indian Ocean, by Charles Meldrum.

Rotation of the wind, by Charles Meldrum.

Die Wirbelstürme, Tornado, und Wettersäulen in der Erd-Atmosphäre. Dr. Th. Reye, Hannover.

Extraordinary hurling of missiles by the Saint Louis tornado of 1871. John H. Tice. (Inland Monthly, July, 1873.)

La velocita del vento, del Prof. D. Ragona. Milano, 1872.

Le burrasche di Novembre 1869. (Rendiconti della Società dei naturalisti di Modena, No. 1.)

Note on the form of cyclones in the Southern Indian Ocean. C. Meldrum. London, 1873.

Vents régnants de l'océan atlantique nord entre les États-Unis et La Manche. (Traverses des paquebots entre La Manche et New York. Révue maritime, etc., juillet 1873.)

REPORT OF THE EXECUTIVE COMMITTEE.

The Executive Committee of the Board of Regents respectfully submit the following report in relation to the funds of the Institution, the receipts and expenditures for the year 1873, and the estimates for the year 1874:

Statement of the fund at the beginning of the year 1874.

The amount originally received as the bequest of James Smithson, of England, deposited in the Treasury of the United States, in accordance with the act of Congress of 10th August, 1846		$515, 169 00
The residuary legacy of Smithson, received in 1865, deposited in the Treasury of the United States, in accordance with the act of Congress of 8th February, 1867		26, 210 63
Total bequest of Smithson		541, 379 63
Amount deposited in the Treasury of the United States, as authorized by act of Congress of 8th February, 1867, derived from savings of income and increase in value of investments		108, 620 37
Total permanent Smithson fund in the Treasury of the United States, bearing interest at 6 per cent., payable semi-annually in gold		650, 000 00
In addition to the above there remains of the extra fund from savings, &c., in Virginia bonds and certificates, viz, consolidated bonds, $58,700; deferred certificates, $29,375.07; fractional certificate, $50.13, now valued at		33, 000 00
Cash balance in United States Treasury at the beginning of the year 1874, as a special deposit, for current expenses		12, 226 68
Amount due from the First National Bank, (present value unknown)	$5, 757 41	
Total Smithson funds, January, 1874		695, 226 68

The Virginia bonds originally puchased by the Institution were as follows:

Five bonds of $10,000 each, (Nos. 146 to 150;) one bond of $5,000, (No. 201,); three bonds of $1,000 each, (Nos. 3497 to 3499;) one bond of $500, (No. 658;) two bonds of $100 each; making in all $58,700.

On the 9th December, 1871, the above bonds were exchanged for Virginia coupon-bonds, consolidated debt, (see Report, 1871, page 105,) as follows:

Fifty-eight bonds, at $1,000 each, (Nos. 11521 to 11578)	$58,000
One bond, at $500, (No. 1380)	500
Two bonds, at $100 each, (Nos. 4192 and 4191)	200
	58,700

These bonds are in the cashier's vault of the United States Treasury, in charge of General Spinner. Coupons due July 1, 1873, and January 1, 1874, are still attached to these bonds.

In addition to the above bonds the institution holds a certificate of indebtedness, (No. 4,543,) deposited with Riggs & Co., from the State of Virginia, (dated July 1, 1871,) for one-third of the amount due for principal and interest surrendered under the provisions of an act of the legislature of 30th March, 1871, this amount having been reserved until an adjustment is made between the States of Virginia and West Virginia as to the old debt of Virginia, amounting to $29,375.07.

There is also a certificate of indebtedness (No. 2,969) for $50.13 for an odd amount of interest.

The uninvested balance in the First National Bank at the beginning of 1873 was $17,811.36. This balance would this year have been increased by a saving of $172.73 had it not been for the suspension of the First National Bank in September last, in which $5,757.41 still remain unpaid, and will probably be, to a considerable extent, a loss.

In accordance with the law of Congress, the interest on the Smithson fund is payable semi-annually, on the 1st of July and 1st January, and from the beginning of the operations of the institution this semi-annual interest was deposited with Messrs. Riggs & Co., until at the meeting of the Board of Regents on the 22d February, 1867, a resolution was adopted directing the deposit of the income in "a national bank which was an authorized Government depository." In accordance with this direction of the Board, the money was deposited in the First National Bank, which proved, however, to be an unsafe curator of the funds. The whole amount on deposit at the time of the suspension of the bank, 19th September, 1873, was $8,224.87, on which, however, a dividend of 30 per cent., or $2,467.46 was paid on the 11th November last, leaving, as stated above, $5,757.41 still due.

Statement of receipts and expenditures in 1873.

RECEIPTS.

From interest on \$650,000, at 6 per cent. in gold	\$39,000 00	
From premium on gold, June and December, ($15\frac{1}{8}$ and $11\frac{1}{2}$%)	5,191 87	
From interest on Virginia stock, (sale of coupons due January 1, 1873*)	1,091 83	
Total receipts		\$45,283 70

EXPENDITURES.

Total expenditures from the Smithson income during 1873, as shown by the detailed statement below	45,110 97
Balance unexpended, which is included in the cash balance in the Treasury	172 73

Statement of expenditures in detail from the Smithson fund for 1873.

BUILDING.

Repairs of the building	\$3,252 23	
Furniture and fixtures	386 26	
		\$3,638 49

GENERAL EXPENSES.

Meetings of the board	\$300 75	
Lighting the building	322 65	
Heating the building	554 38	
Postage	971 10	
Stationery	394 91	
Incidentals	757 47	
Salaries and clerk hire	12,429 96	
Purchase of books and periodicals	411 34	
		16,142 56

PUBLICATIONS AND RESEARCHES.

Smithsonian contributions, quarto	\$8,706 08
Miscellaneous collections, octavo	4,514 46
Reports, octavo	593 55

*Interest on \$58,700 coupons at 3 per cent		\$1,761 00	
Deduction of one-third for West Virginia	\$587 00		
Deduction for State tax	73 37		
Deduction for charge of Riggs & Co.'s commission	8 80		
		669 17	
Net amount received			\$1,091 83

Meteorology and researches	$3,232 81	
Apparatus	815 09	
Laboratory	109 88	
Explorations	228 00	
Lectures	600 00	
		$18,799 87

EXCHANGES.

Literary and scientific exchanges through agencies in London, Paris, Leipsic, Amsterdam, Milan, &c	6,251 74

MUSEUM.

Incidentals in addition to Government appropriation	278 31
Total expenditure from Smithson fund in 1873	45,110 97

During the past year the Institution has advanced money for the payment on account of the Government for freights on specimens, purchase of apparatus for Government expeditions, &c., the repayments of which, together with the amount received for sales of publications, &c., have been deducted from the several items of the foregoing expenditures, as follows:

From museum, for repayments for freight	$967 46
From museum, for repayments for labor, &c	510 00
From exchanges, for repayments for freight	196 95
From apparatus, for instruments for expeditions	394 67
From postage, for repayments	37 45
From building, for repayments	1,258 37
From heating, for repayments	325 21
From cost of books, for repayments	33 00
From Smithsonian contributions, from sales	99 07
From Smithsonian miscellaneous collections, from sales	119 95
From Smithsonian reports, from sales	16 00
From incidentals, from sales old material	35 35
Total repayments and miscellaneous credits in 1873	3,993 48

NATIONAL MUSEUM.

For several years past Congress has made an annual appropriation of $15,000 for the support of the National Museum, under the care of the Smithsonian Institution, and it has also in the last two years appropriated $25,000 for the completion and fitting up of the halls required for the Government collections, and $12,000 for the introduction of

steam-heating apparatus. The following is a tabular statement of the condition of these funds at the present time:

Appropriation for preservation of collections for fiscal year ending June 30, 1874. (Statutes at Large, vol. 17, p. 518)	$15,000 00	
Amount expended to 31st December, 1873. (See Museum journal A, p. 55)	7,500 00	
Balance for support of museum to June 30, 1874		$7,500 00
Appropriation for completion of the hall required for the Government collections. (Statutes at Large, vol. 17, p. 361.)	10,000 00	
(The whole of this has been expended. See Museum journal A, p. 509.)		
Appropriation for fitting up the new halls required for the Government collections. (Statutes at Large, vol. 17, p. 518)	$15,000 00	
Amount expended to 2d January, 1874. (See Museum journal A, p. 519)	9,449 08	
Balance unexpended, but due on contracts		5,550 92
Appropriation for steam-heating apparatus. (Statutes at Large, vol. 17, p. 518)	12,000 00	
Amount expended to 31st December, 1873. (See Museum journal A, p. 533)	8,537 97	
Balance unexpended, but due on contracts		3,462 03
Balances, January, 1874		9,012 95

Previous to 1873 all the disbursements on account of the appropriations of Congress for the support of the National Museum were made directly by the Institution and afterward refunded by the Department of the Interior; but during the past year as strict a division of the accounts as possible has been made, and those relating to the museum have been paid directly by the disbursing agent of the Department of the Interior.

THE FOLLOWING ARE THE ESTIMATES FOR THE YEAR 1874:

RECEIPTS.

Interest on the permanent fund, receivable 30th June, 1874, in gold	$19,500	
Interest on the permanent fund, receivable 31st December, 1874, in gold	19,500	
Probable premium on gold, 10 per cent	3,900	
Interest on Virginia bonds	2,000	
		$44,900

APPROPRIATIONS.

For building	2,000	
For general expenses	14,000	
For publications and researches	20,000	
For exchanges	7,000	
For books and apparatus	500	
For contingencies	1,400	
		44,900

The executive committee have examined eight hundred and eighty-five receipted vouchers for payments made during the four quarters of the year 1873. In every voucher the approval of the Secretary of the Institution is given, and the certificate of an authorized agent of the Institution is appended, setting forth that the materials and property and services rendered were for the Institution, and to be applied to the purposes specified.

The quarterly accounts-current, bank-book, check-book, and ledger have also been examined and found correct, showing a balance in the care of the Treasurer of the United States, 13th January, 1874, of $12,226.68.

Respectfully submitted.

PETER PARKER,
JOHN MACLEAN,
W. T. SHERMAN,
Executive Committee.

JANUARY 24, 1874.

REPORT ON THE APPROPRIATIONS AND DISBURSEMENTS FOR THE NATIONAL MUSEUM.

Since the foregoing report was presented to the Board of Regents and accepted by them, as authorized by a resolution of the board, January 26, 1874, the undersigned, members of the executive committee, have exam-

ined the accounts of appropriations and disbursements for the National Museum for the year 1873, and find for each disbursement a voucher approved by the Secretary of the Smithsonian Institution, and a certificate of an authorized agent of the Institution appended, setting forth that the account is correct, the articles or services charged therein were required, and furnished on account of the objects specified, and that the same were necessary, and the charges reasonable.

The undersigned have also examined the journal and ledger of the National Museum, and find the balances remaining, on the 1st of January, 1874, of the appropriations of Congress for Smithsonian building and for preservation of collections in the National Museum to correspond with the certificate of the 2d February, 1874, of the disbursing clerk of the Interior Department, viz: Smithsonian building, 1874, \$9,012.95, (see page 518, journal A;) preservation of collections, 1874, \$7,500, (see page 55, journal A;) total balance, \$16,512.95.

The other member of the committee (Dr. Maclean) was obliged to leave the city previous to this examination.

Respectfully submitted.

PETER PARKER,
W. T. SHERMAN,
Executive Committee.

WASHINGTON, *February* 5, 1874.

JOURNAL OF PROCEEDINGS

OF

THE BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION.*

WASHINGTON, *December* 19, 1873.

A special meeting of the Board of Regents was held at 7 p. m. at the institution. Present, Mr. Justice Nathan Clifford, acting Chief Justice of the United States, Hon. H. Hamlin, Hon. J. A. Garfield, Hon. L. P. Poland, Hon. Peter Parker, General Sherman, and the Secretary, Professor Henry.

The Secretary stated that the meeting had been called for the purpose of electing a chancellor in place of Chief Justice Chase, who had deceased, and that this was a case of emergency, as the semi-annual interest, due on the first of next month, necessary to carry on the operations of the Institution, could only be drawn according to law on the requisition of the chancellor and secretary of the Institution.

On motion of General Garfield, Mr. Justice Nathan Clifford was elected chancellor.

The Secretary announced that since the last meeting of the board two of its most prominent and valuable members had deceased, Chief Justice Chase and Professor Agassiz.

On motion of Mr. Hamlin, a committee was appointed to prepare resolutions expressing the sentiments of the board in regard to the death of Mr. Chase and Professor Agassiz.

The chancellor appointed Messrs. Hamlin, Sherman, Parker, and the Secretary as the committee.

General Garfield made the following remarks:

MR. CHANCELLOR: I rise to second the motion for the appointment of a committee to draught resolutions in reference to the death of our distinguished brother regents Chief Justice Chase and Professor Agassiz.

Never before in a single year has the Board of Regents suffered so severe a loss. It would be difficult to find, in any organization, two men more eminent, and representing a wider range of culture, than the two regents who have fallen since the last meeting of this board.

* Continued from page 86, Report for 1872.

This is not the occasion to speak at length on the subject; but as my term of service will expire before the next meeting, I ask the indulgence of the board while I refer briefly to some of the marked characteristics of our late distinguished associates.

Few Americans have filled so many high places of trust and honor as Salmon P. Chase; and few have brought to the discharge of the duties of their high station such masterly ability and such rare and varied accomplishments. His career adds another to the many illustrations of the truth, that he who loses his life for the truth's sake shall find it.

In his early manhood, following his own conviction of duty, he committed himself, without reserve, to a cause which seemed, at the time, to shut him out from all hope of public preferment. He stood by his convictions, and lived, not only to see his doctrines prevail, but to be one of the honored leaders in the cause he had espoused.

Whether at the bar, in the practice of his profession; in the executive chair of his own State; in the National Senate; as the great finance minister of the republic in the stormy days of war; or as Chief-Justice of the United States, there ran through his whole life a depth of conviction, a clearness of comprehension, and a force of utterance that made his power felt, and marked him as a man who filled and overfilled, honored and adorned, the great stations to which he was called. If, in the course of his high career, he felt the promptings of that ambition which has been called "the last infirmity of noble minds," it must be acknowledged that he aspired to no place beyond his capacity to honor.

Throughout his long and honored life the cares and demands of public place did not diminish his ardent love for the pursuits of science and the keen enjoyment of literature and art. The great masters of song were his daily companions. I was his guest for many weeks, during the stormy and troublous winter of 1862–'63, when to the deep anxieties of the war were added the gravest financial problems that have ever confronted an American Secretary of the Treasury. And many a time, at the close of a weary day of anxious care and exhausting labor, I have seen him lay aside the heavy load, and, in the quiet of his study, read aloud, or repeat from memory, the rich verse of Tennyson, or of some other great master of song.

It was this life of art and sentiment, within the stormy life of public duty, that fed and refreshed his spirit, and kept his heart young, while his outer life grew venerable with years and honors.

As the Chancellor of this Institution, we saw in happy and harmonious action his ample knowledge of our institutions, his wide experience of finance, his reverential love for science and art, and his unshaken faith in the future of his country as the grand theater for the highest development of all that is best and greatest in human nature. No contribution to science offered to this board escaped his attention. Nothing that was high or worthy in human pursuits failed to elicit his appreciative and powerful support.

In Professor Agassiz we have lost a man of kindred powers, whose life was spent in a different though hardly less conspicuous field of action.

Few lives were ever so sincerely and entirely devoted to the highest and best aims of science. I was led to appreciate this by a remark which Professor Agassiz made to me several years ago, which is, I believe, the key to his own career, and deserves to be remembered by all who would follow in his footsteps. His remark was that he had *made it the rule of his life to abandon any intellectual pursuit the moment it became commercially valuable.*

He knew that others would utilize what he discovered; that when he brought down the great truths of science to the level of commercial values, a thousand hands would be ready to take them and make them valuable in the markets of the world. Since then I have thought of him as one of that small but elect company of men who dwell on the upper heights, above the plane of commercial values, and who love and seek truth for its own sake. Such men are indeed the prophets, the priests, the interpreters of nature. Few of their number have learned more, at first hands, than Professor Agassiz; and few, if any, have submitted their theories to severer tests.

It was a great risk for the astronomer to announce that the perturbations of the solar system could only be accounted for by a planet as yet unknown, and to predict its size and place in the solar system, trusting to the telescope to confirm or explode his theory. But perhaps Professor Agassiz took even a greater risk than this. Who does not remember the letter he addressed to Professor Peirce, of the Coast Survey, just before he set out on the Hassler expedition, predicting in detail what evidences of glacial action he expected to find on the continent of South America, and what species of marine animals he expected to discover in the deep-sea soundings along that coast? He risked his own reputation as a scientific man on the predictions then committed to writing.

What member of this board will forget the lecture he delivered here after his return, detailing the discoveries he had made, and showing how completely his predictions had been verified?

While he was the prince of scholars, and a recognized teacher of mankind, yet he always preserved that childlike spirit which made him the most amiable of men. He studied nature with a reverence born of his undoubting faith. He believed that the universe was a cosmos, not a chaos; and that throughout all its vast domains there were indubitable evidences of creative power and supreme wisdom.

We have special cause for regret that his early death has deprived this community and the world of a series of lectures which were to have been delivered here this winter, on subjects of the deepest interest to science. His death will be deplored in whatever quarter of the globe

genius is admired and science is cherished. He has left behind him as a legacy to mankind a name and a fame which will abide as an everlasting possession.

The Secretary stated that prior to February 22, 1867, the money received from the United States, as semi-annual interest on the bequest of Smithson, was deposited with the bankers Corcoran & Riggs, and subsequently with Riggs & Co., but on that date the regents had adopted a resolution directing that all money received by the Institution "be deposited in a national bank, which is also an authorized Government depository," (Report for 1866, page 78.) In accordance with this instruction and the direction of the chancellor, Chief Justice Chase, the income was deposited in the First National Bank of Washington. Unfortunately, on the 19th of September, 1873, that bank suspended payment, having $8,224.87 to the credit of the Institution. Since that time, however, a dividend of 30 per cent. ($2,467.46) has been received on this balance, leaving $5,757.41 still due the Institution.

On motion of General Garfield, it was

Resolved, That the Secretary of the Institution make arrangements, if possible, with the Secretary of the Treasury to deposit the income hereafter received in the United States Treasury, to be drawn out on checks signed by Professor Henry; and that if this course could not be adopted, that Congress be requested to pass a law to this effect.

The board then adjourned *sine die*.

WASHINGTON, *January*, 21, 1874.

In accordance with a resolution of the Board of Regents of the Smithsonian Institution, fixing the time of the beginning of their annual meeting on the third Wednesday in January of each year, the board met to-day at 7 o'clock p. m. Present: Mr. Associate Justice Clifford, chancellor, Hon. H. Hamlin, Hon. J. W. Stevenson, Hon. A. A. Sargent, Hon. S. S. Cox, Rev. Dr. Maclean, Hon. Peter Parker, General Sherman, Governor Shepherd, Prof. H. Coppée, and Professor Henry, Secretary.

The minutes of the last meeting were read and approved.

The Secretary announced the following appointments as regents:

By joint resolution of Congress (approved January 19, 1874) Prof. Asa Gray, of Harvard College, Cambridge, Massachusetts, vice Prof. L. Agassiz, deceased; Prof. J. D. Dana, of Yale College, New Haven, Conn., vice Professor Woolsey, declined re-election; Prof. Henry Coppée, of Lehigh University, Bethlehem, Pa., vice William B. Astor, declined re-election; Rev. Dr. John Maclean, of Princeton, N. J., and Hon. Peter Parker, of Washington, D. C., re-elected for the term of six years.

By the President of the Senate Hon. A. A. Sargent, of California, as regent for the term of his service as Senator, (1879,) vice Mr. Trumbull.

By the Speaker of the House, Hon. S. S. Cox, of New York, re-appointed, and Hon. E. Rockwood Hoar, of Massachusetts, vice Hon. J. A. Garfield, and Hon. G. W. Hazelton, of Wisconsin, vice Hon. L. P. Poland; for two years from the fourth Wednesday of December, 1873.

Mr. Hamlin, from the special committee appointed at the last meeting, reported the following resolutions:

Resolved, That in the death of Chief Justice Chase, the Smithsonian Institution has lost a wise counsellor, an efficient friend, and a zealous advocate of its policy and operations.

Resolved, That in his death, the country has lost an elevated statesman, a wise, a just, and an upright judge.

Resolved, That the cause of civil liberty, of pure Christianity, and the advance of higher civilization have lost in the death of Chief Justice Chase the co-operation of one of the most prominent and influential minds of the day.

Resolved, That a copy of these resolutions be transmitted to the family of the deceased.

Mr. Hamlin made the following remarks:

I did not expect to utter a word on this occasion. I have, however, at the solicitation of the Secretary, been induced to make some brie remarks upon the subject of the resolutions reported by the committee. I first met Mr. Chase at the time when he entered upon his official duties as a Senator of the United States, and from that time to the close of his life I knew him well and intimately. This Institution has lost an earnest, able, and devoted friend, and that we shall miss him in our counsels we well know, much better than the world, for we always found him at the post of duty, uniting with a broad and capacious intellect, good, common, practical sense, and always ready to counsel well and wisely. We shall miss him here. In the counsels of the nation he did his duty well and nobly. He had what at the time were called his peculiar opinions, and he avowed and maintained them at a time when it required moral courage to do so; but, however others disagreed with him, none would say that he did not advocate his views with courtesy and eminent ability. In the heat of debate he might sometimes make a quick retort, but his bearing was always that of a gentleman, and his position that of an elevated statesman. On these occasions he did what he believed would subserve the best interests of man and elevate him to a higher and nobler civilization. As an executive officer during the war, he administered the Treasury Department with great ability, and his name and fame will be connected with those times in the history of the country. To him, more than any other man, are we indebted for the means by which the

life of the nation was saved. I knew less personally of him in judicial life, but I think it is known and well understood through all the land that he wore the judicial ermine with honor and untarnished; that he commanded the respect due to his judicial and legal learning, and that his decisions comported well with those of the eminent men who had occupied the same exalted position, and was a worthy successor of those who preceded him.

On motion of General Sherman, the resolutions were unanimously adopted.

Mr. Hamlin, from the same committee, also reported the following resolutions:

Resolved, That the Board of Regents of the Smithsonian Institution record on the minutes of their proceedings their high appreciation of the character and labors of their lamented associate, Louis Agassiz, and the expression of their profound sorrow on account of his unexpected death, in the full exercise of his power, and amidst his unparalleled usefulness.

Resolved, That Professor Agassiz, by the attraction which he exerted on all who came under the magical influence of his genial temperament and generous sympathies, nobly advocated the claims of science to high popular estimation, private endowments, and liberal public patronage.

Resolved, That as an instructor in his adopted country, he introduced methods of study and directed attention to fields of research in natural history far more elevated than those which had been previously in use; that as an original investigator he made additions to human knowledge which do honor to the science of the nineteenth century, and associate his name with those of the prominent benefactors of his race.

Resolved, That in the death of Professor Agassiz, the Smithsonian Institution has lost a wise adviser in its scientific operations, a powerful supporter of its policy in regard to original research, and an influential friend, ready at all times to advocate its claims on Congress for the independent support of a national museum.

Resolved, That the Board of Regents deeply sympathize with the family of the deceased, on account of their sad bereavement, and that a copy of these resolutions be transmitted to them.

Dr. Parker spoke as follows:

Mr. CHANCELLOR: It may seem presumptuous in me to rise to move the adoption of the resolutions submitted.

To calculate the distance and magnitude of the sun, requires an astronomer, and to analyze its chemical properties is the province of the spectroscopist, but multitudes who are neither astronomers nor spectroscopists can delight in the revelations which are made in regard to that luminary.

I am not a scientist; still, I can appreciate, in some degree, the labors of one who shone *a star of the first magnitude* in the firmament of science!

It is sixteen years since I first met Professor Agassiz, whose death the Board of Regents so deeply lament. It was at commencement at Harvard University, in 1858, the first year after my return from a long residence in China. The Emperor Napoleon had made tempting offers in the way of high position to Professor Agassiz to go to Paris. Intense solicitude on the part of his friends in Cambridge and the country generally, was felt as to his decision. It was on this occasion that their anxious suspense was relieved, as Professor Agassiz, after dinner, rose and announced his determination henceforth to be an American citizen. This declaration was received with most enthusiastic demonstrations of rejoicing.

I am happy the resolutions now submitted recognize his adopted citizenship. An incident that has come to my knowledge within the last hour has given me great pleasure, as illustrating the patriotism of the man. A mutual friend said, "Professor Agassiz, it fills me with gratitude every time I think of your declining the very flattering proposition that was made to you from the court of France." To which he replied: "Yes, and do you know that proposition was renewed to me after the war began, and I replied with *more earnestness* than before, if I loved my adopted country too much to leave it when all was peace, I certainly shall not leave it now, when a shadow has come over its prospects."

In the resolutions adopted by different scientific and literary institutions throughout the country, much prominence is given, and rightly, too, to the irreparable loss sustained by the decease of this pre-eminent man of science.

While we sympathize most fully with that sentiment, there is another consideration that should not be overlooked. I refer to the kind Providence that has given to the world such a man, preserved his life to mature years, and enabled him to accomplish so much as he has done for the science, not only of the day and of this country, but of the age and world.

To Louis Agassiz belongs the distinction of having awakened, in a remarkable degree, a spirit of scientific inquiry, and of having discovered changes our planet has undergone, through the influence of laws he was the first to demonstrate, arriving at such a knowledge of their operations that it may be truly said of him that the remote consequences of these laws, *first predicted by his theory, were, in repeated instances, most signally verified upon two continents by his observations.*

In the circumstances of his departure from this life, there were peculiar mercies that call for grateful recognition. Fears were at one time entertained, and not without cause, lest he might linger through years of suffering, deprived of reason; but he and his loving family have been spared that affliction, and he has been, as it were, translated, to resume, or rather to continue, on a higher plane, his advance in the knowledge of the works of the Creator, with devout and endlessly increasing adoration of their Divine Author.

On motion of Dr. Parker, the resolutions were unanimously adopted.

The Secretary presented a general statement of the condition of the fund, and the receipts and expenditures for the year 1873, which was referred to the executive committee.

The Secretary called attention to the liberality of Mr. George W. Riggs, the banker, who, after the suspension of the First National Bank, in September last, had advanced the funds necessary to carry on the operations of the Institution, amounting to upward of $10,000, on which he had declined to charge any interest.

On motion of Mr. Hamlin, it was

Resolved, That the cordial thanks of the Board of Regents be tendered to Mr. Riggs, for his generosity in his financial services to the Institution.

The Secretary stated that, in accordance with the resolution of the Board, he had applied to the Treasury Department to take charge of the Smithsonian funds for current operations, and that arrangements had been made with General Spinner, United States Treasurer, to receive deposits from the Institution, and make payments on checks of the Secretary, in the same manner as had been done in the First National Bank.

The Institution is indebted to General Spinner for his prompt acquiescence in the proposition, and his authority for carrying it out in all the details necessary to facilitate its operation.

The Secretary gave an account of the history and operations of the Institution, particularly for the information of the new members of the board.

The board adjourned at 9 p. m., to meet on Monday, 26th January, at 7 o'clock p. m.

JANUARY 26, 1874.

A meeting of the Board of Regents was held this day at 7 o'clock p. m. Present Mr. Justice Clifford, chancellor of the Institution, Hon. H. Hamlin, Hon. J. W. Stevenson, Hon. A. A. Sargent, Hon. E. R. Hoar, Hon. G. W. Hazelton, Hon. P. Parker and the Secretary, Professor Henry.

The minutes of the last meeting were approved.

Dr. Parker presented the annual report of the executive committee, which was read and, on motion of Mr. Stevenson, adopted.

The Secretary called attention to the bequest of James Hamilton, and presented the following letter from one of the executors:

CARLISLE, PA., *January* 23, 1874.

DEAR SIR: Yours of 20th instant received and contents noted. The executors will be ready to pay over the legacy (bequeathed by Mr.

Hamilton) to the Smithsonian Institution about the first week in February. Please inform us who is authorized by the Board of Regents of the Smithsonian Institution to receive the legacy and release the executors, and we will send the release next week to you to be executed by the proper officers of said board, and one of the executors or a representative will be in Washington in the early part of next month to pay over the money and get the release.

Yours, respectfully,

JOSEPH A. STUART,

One of the executors of Jas. Hamilton, deceased.

Prof. JOSEPH HENRY.

N. B.—Below you will notice a copy of the section of the will containing said legacy to the Institution.

SECTION 8. "I give one thousand dollars to the Board of Regents of the Smithsonian Institution, located at Washington, D. C., to be invested by said regents in some safe fund, and the interest to be appropriated biennially by the secretaries, either in money or a medal, for such contribution, paper, or lecture, on any scientific or useful subject, as said secretaries may approve."

On motion of Mr. Hamlin, it was

Resolved, That the bequest of the late James Hamilton, of Carlisle, Pa., be accepted; that the chancellor and Secretary of the Institution be authorized to receipt for the money and that it be deposited with the Secretary of the Treasury, on the same terms as the original bequest of Smithson, in accordance with the act of Congress approved 8th February, 1867.*

The Secretary gave an account of the correspondence of the Institution and spoke of the immense mental activity which existed in this country in regard to scientific speculations. In connection with these remarks he laid before the Board, at the request of the author, a series of manuscripts entitled "Disclosures in Science, etc," by Henry Korner, of Powhatan, Ohio, which had been urged upon the Institution for publication. In these manuscripts the author states that he has demonstrated the insufficiency of the theory of gravitation, as propounded by Newton, to explain the mechanical phenomena of astronomy, and also the inadequacy of the received principles of molecular action to account for the phenomena of physics and chemistry, and that he has himself discovered principles to which all these may be referred.

The Secretary stated that after examining these manuscripts he had informed the author that they could not be published by the Institution, since nothing could be accepted for that purpose unless it had previously been submitted to a commission for critical examination, and a favorable report had been obtained; that these speculations were

*Statues at Large, vol. 14, page 391.

either so far in advance of the received scientific principles of the day or so far behind them that the two were out of all harmony with each other; that it would be impossible to obtain a favorable report in regard to them from any commission composed of men of scientific reputation; that he would, however, suggest that the mauscripts be deposited in the archives of the Institution, free of access to any who might wish to consult them with the proviso that no extracts be taken from them without full credit being given to the name of the author. This suggestion was favorably received by the author.

On motion of Mr. Stevenson, it was

Resolved, That the action of the Secretary in relation to the Korner manuscripts be approved.

The Secretary stated that, in accordance with the policy of the Institution to enter into harmonious relations with other establishments in this city, as had already been done by depositing the plants and insects in the Department of Agriculture, the skulls in the Army Medical Museum, &c., he desired to enter into friendly relations with the Corcoran Art-Gallery, of which he had recently been elected a trustee. He thought that, inasmuch as this gallery had been opened to the public, and had been established with a permanent endowment, larger even than that of the Smithsonian Institution, it was proper that some of the articles of art now in the building should be deposited in the Corcoran Gallery, subject, of course, to the order of the regents.

On motion of Mr. Hamlin, it was

Resolved, That the Secretary be authorized to deposit in the Corcoran Art-Gallery, to be reclaimed at any time, such works of art belonging to the Institution as may be approved by the executive committee.

The Secretary presented his annual report of the operations of the Institution for the year 1873, which was read; and

On motion of Mr. Hazelton,

Resolved, That the report of the Secretary be accepted and transmitted to Congress as usual.

The Secretary stated that during the past year Mr. P. T. Barnum had presented the National Museum with the following valuable specimens of natural history, viz: A Malayan tapir, a Bactrian camel, a dromedary, an African panther, a Florida manatee, an Indian rhinoceros, a mandrill, and others, furnishing the means of preparing both their skeletons and mounted skins. He had also promised to give the Institution the bodies of all the animals that die in his menagerie.

On motion of Dr. Parker, it was

Resolved, That the thanks of the Board of Regents be tendered to P. T. Barnum, esquire, for his liberal donation of the bodies of animals to the National Museum, which form a very important addition to the collection of specimens necessary to illustrate the science of zoology.

Dr. Parker stated that prior to 1873 all accounts for the museum had been paid in the first instance by the Institution and audited with the Smithsonian vouchers by the executive committee. Last year, however, an arrangement had been made by which bills for the National Museum, after approval by Professor Henry, were presented to the disbursing agent of the Department of the Interior, who paid the parties directly. The accounts were audited by the disbursing officer of the Interior Department, and afterward by the Treasury Department. Inasmuch as the regents of the Institution, however, are responsible for all expenditures connected with its operations, he would ask the opinion of the board as to the propriety of examining all the vouchers for payments made for the National Museum from the Government appropriations. Professor Henry had retained a duplicate set of vouchers for these payments, and had the books carefully kept, and had offered them to the committee for examination.

On motion of Mr. Hoar, it was

Resolved, That the board approve of the examination by the executive committee of the vouchers for the expenditures of the National Museum, as requested by the committee and desired by the Secretary.

The Secretary stated that the system of international literary and scientific exchanges had now become so extensive that he feared the cost would be too great for the means of the Institution, and it had been suggested that the larger societies and establishments which received so much benefit from the system might contribute something annually for its support. After some discussion,

On motion of Mr. Hamlin, it was

Resolved, That the Secretary be authorized to receive aid from societies and individuals in defraying the heavy expense of the exchange system.

The board then adjourned to meet at the call of the Secretary.

APRIL 27, 1874.

A meeting of Board of Regents was held at 10 o'clock a. m.

Present: The Chief Justice of the United States, Hon. M. R. Waite, Hon. Peter Parker, Hon. E. R. Hoar, Hon. G. W. Hazelton, Professor Asa Gray, and the Secretary, Professor Henry.

The minutes of the last meeting were read and approved.

The Secretary stated that the object of the meeting was the election of a chancellor.

On motion of Mr. Hoar, Chief Justice Waite was unanimously elected chancellor.

Dr. Parker, from the executive committee, presented a report on the examination of the accounts of the National Museum for 1873, and a

statement relative to the accounts of the Institution and of the National Museum for the first quarter of 1874; which were accepted.

The Secretary stated that, on the 24th of February, 1874, Mr. Joseph A. Stuart, one of the executors of the estate of the late James Hamilton, of Carlisle, Pennsylvania, had paid the legacy of said Hamilton, viz, one thousand dollars, into the Treasury of the United States, in accordance with the resolution of the Board of Regents adopted January 26, 1874.

The following is a copy of the receipt:

No. 10,564.] TREASURY OF THE UNITED STATES,

Washington, D. C., February 24, 1874.

I certify that Prof. Joseph Henry, Secretary of the Smithsonian Institution, has this day deposited to the credit of the United States one thousand dollars, on account of amount received by bequest of the late James Hamilton, of Carlisle, Pennsylvania, accepted by the Board of Regents by resolution of January 26, 1874, providing that the amount be deposited with the Secretary of the Treasury on same terms as the original bequest of Smithson, in accordance with act of February 8, 1867,* for which I have signed duplicate receipts.

$1,000. L. R. TUTTLE,

Assistant Treasurer United States.

The Secretary gave an account of the operations of the Institution; and after inspecting the building, the board adjourned *sine die.*

* Statutes at Large, vol. 14, page 391.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1873.

The object of this appendix is to illustrate the operations of the Institution by reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the meteorological observers and other persons interested in the promotion of knowledge.

CHARLES BABBAGE.

[COMPILED FOR THE SMITHSONIAN INSTITUTION.]

Charles Babbage, upon being urged to write his own biography, replied that he had no desire to do it while he had strength and means to do better work. Some men, he said, write their lives to save themselves from *ennui*, careless of the amount they inflict on their readers; others, lest some kind surviving friend in showing off his own talent in writing personal history might show up theirs; and others still from fear that the vampires of literature might make them a prey. He belonged to no one of these classes. What a man had done for others, not what he might say about himself, formed his best life. And so to many who asked him to prepare an autobiography he sent a list of his works, "which," he naively adds, "no one cared to insert." Still, few persons who have made a name while living are insensible to posthumous fame, and Babbage was among the number. While professing to treat these applications lightly, he nevertheless set about placing on record an account of himself, and though he rejects the name of autobiography, he has left behind him, in a work which he entitles "Passages from the Life of a Philosopher," a memoir which in variety of detail and clearness of description, liveliness of style and sententious remark, is almost without its parallel. Without being confined to this witty and erratic narrative, and putting the estimate of the thinking men of the age rather than his own upon what he was and what he did, this notice will aim to do justice to certainly not the least remarkable man of this nineteenth century.

Of the mere personal history of this eminent philosopher and scientific mechanist little need be recorded. He was born of gentle blood and moderate competence on December 26, 1792. From earliest years he showed great desire to inquire into the causes of things that astonish childish minds. He eviscerated toys to ascertain their manner of working; he sought to prove the reality of the devil by drawing with his blood a circle on the floor and repeating the Lord's prayer backward; he dissipated toothaches by reading Don Quixote; he bargained with another boy that whoever died first should appear to the survivor, and spent a night of sleeplessness when the first event of the compact occurred, awaiting in vain his comrade's appearance. In college he was perpetually puzzling his tutors by abstruse questions. When the circulation of the Bible with or without comment became a fierce controversy at Cambridge, he formed, with Herschel, Maule,

D'Arblay, and others, an analytical society for the translation of Lacroix's Differential and Integral Calculus, maintaining that the work needed no comment; that the "d's" of Leibnitz were perfect, and consigning to perdition all who supported the heresy of Newton's "dots." It being hinted that the society was infidel, the young student replied, "No! We advocate the principles of pure 'D'-ism in opposition to the 'Dot'-age of the university." He studied the game of chess and beat every expert that was brought against him; formed a ghost club to collect all reliable evidence of the supernatural; joined high players at whist in order to show them that, staking only shillings, he could win at guinea-points; embarked in boating not more from the manual labor than from the intellectual art of sailing; and by making a collection of examples of mathematical problems, in which the notation of Leibnitz was employed, he made it for the interest of tutors of the colleges to abandon the symbols of Newton.

During Babbage's college life the course of his studies led him into a critical examination of the logarithmic tables then in use. The value of these tables had long been recognized in every part of the civilized world. Large sums of money were expended in their preparation, and the greatest care produced only proximate accuracy in the calculations. The young mathematician set himself to consider whether, in the construction of these tables, in place of the perturbable processes of the intellect, it were not possible to substitute the unerring movements of mechanism. The thought was perpetually recurring during the latter portion of his college course. He gave up his leisure time to experiments having this end in view—discussed the subject with Herschel, Ryan, Maule, and others of his class who were interested in philsophical mechanism, and was no sooner graduated than he visited the various centers of machine labor in England and on the continent, that he might become familiar with the combinations in use and study their functions. Returning home, he began to sketch arrangements for a machine by which all mathematical tables might be computed by one uniform process.

The idea of a calculating machine did not originate with young Babbage. Pascal, nearly two hundred years before, had constructed, when in his nineteenth year, an ingenious machine for making arithmetical calculations, which excited admiration. In his *Pensées*, alluding to this engine, he remarks: "*La machine arithmétique fait des effets qui approchent plus de la pensée que tout ce que font les animaux; mais elle ne fait rien qui puisse faire dire qu'elle a de la volonté comme les animaux.*" Subsequently, Leibnitz invented a machine by which arithmetical computations could be made. Polenus, a learned and ingenious Italian, put together wheels by which multiplication was performed; and in the various industrial exhibitions since 1851, contrivances for performing certain arithmetical processes have been exhibited. The principle upon

which Babbage's engines have been constructed, however, is entirely new, and intended to do work of a much more important character.

On the 1st of April, 1823, a letter was received from the treasury by the president of the Royal Society, requesting him to ask the council to take into consideration a plan which had been submitted to government by Mr. Babbage for applying machinery to the purposes of calculating and printing mathematical tables, and desiring to be favored with its opinion on the merits and utility of the invention. This is the earliest allusion to the calculating machine on the records of the Royal Society. The invention, however, had been brought before the members in the previous year by a letter from Mr. Babbage to Sir Humphry Davy. In that he had given an account of a small model of his engine for calculating differences, which produced figures at the rate of 44 a minute, and performed with rapidity and precision all those calculations for which it was designed. He had concluded this letter by saying, "that though he had arrived at a point where success was no longer doubtful, it could be attained only at a very considerable expense, which would not probably be replaced by the works it might produce for a long period of time; and which is an undertaking I should feel unwilling to commence, as altogether foreign to my habits and pursuits."

The council of the Royal Society appointed a committee to take Mr. Babbage's plan into consideration. It was composed of the following gentlemen: Sir H. Davy, Mr. Brande, Mr. Combe, Mr. Baily, Mr. Brunel, Mr. Colby, Mr. Davies Gilbert, Sir John Herschel, Captain Kater, Mr. Pond, Dr. Wollaston, and Dr. Young. On the 1st of May, 1823, this committee reported: "That it appears Mr. Babbage has displayed great talents and ingenuity in the construction of his machine for computation, which the committee think fully adequate to the attainment of the objects proposed by the inventor, and that they consider Mr. Babbage as highly deserving of public encouragement in the prosecution of his arduous undertaking." This report was transmitted to the lords of the treasury, by whom it was printed and laid before Parliament. Two months after this a letter was sent from the treasury to the Royal Society, informing them that the issue of £1,500 had been directed to Mr. Babbage "to enable him to bring his invention to perfection in the manner recommended."

It is not within the purpose of this memoir to describe the misunderstanding which arose between Mr. Babbage and the British government, during the following twenty years, in consequence of this letter, received by the Royal Society from the lords of the treasury. He regarded the machine he now undertook to build as the property of the government. They understood it to be his. He received the first advance of money as an earnest that all necessary funds would be furnished to complete this difference engine No. 1. They seemed to have regarded it in the light of a temporary assistance, given to a man of genius for the purpose of en-

abling him to complete an invention which would be of great public benefit. He commenced the work, giving his own labors gratuitously, according to what he considered to be an order. Government looked on, furnished further moneys, consulted the Royal Society once and again as to the progress of the work, but declined committing itself further. Mr. Babbage advanced considerable sums, but was not reimbursed; made great improvements upon his original plans, but was not encouraged; carried with him the convictions of the scientific men of his country and continental Europe, but was left behind by the treasury; and finally, when, in the opinion of such philosophical mechanists as Sir John Herschel, Sir Mark Brunel, Mr. Pond, the astronomer royal, and others, he was on the eve of results far surpassing in importance all that had been contemplated, he was informed that "ultimate success appeared so problematical and the expense so large and so utterly incapable of being calculated, that the government would not be justified in taking upon itself any further liability."

Thus terminated in 1842 the engagement which had existed more than a score of years between Charles Babbage and the British government. During this period of time he had made heavy sacrifices, both pecuniary and personal, had refused highly honorable and profitable situations; had employed in his own house, at his own expense, the most intelligent and skilled workmen to assist him in making experiments necessary for attaining a knowledge of every art which could possibly tend to the perfection of his engine; had repeatedly, at his own expense, visited the manufactories of England and the continent; had invented incidentally, and constructed, mechanical tools and labor-saving machines of great public value, not one of which he protected by letters-patent, and had gratuitously given the results of his energetic mind to the perfect construction of the machines which he regarded as the great purpose of his life. Whether success would have equaled expectation had his government rendered him the required aid, can never be known. He has left behind him no thinker or philosophical mechanic capable of completing his work.

It was to calculate and print tables of figures connected with various sciences; with almost every department of the useful arts; with commerce, astronomy, navigation, surveying, engineering, and everything which depends on mathematical measurements.

To show the immense importance of any method by which these numerical tables, absolutely accurate in every individual copy, could be produced with facility and cheapness, let the reader revert to what European governments have attempted to do in the last hundred years. Dodson's Calculator, published in London in 1747, contained a table of multiplication extending to 10 times 1,000. In 1775 this table was extended to 10 times 10,000. The English board of longitude employed Dr. Hutton, in 1781, to calculate numerical tables up to 100 times 1,000; and to add to these, tables of the squares of numbers as far as 25,400;

and also tables of cubes of the first ten powers of numbers reaching to 100. In 1814, Professor Barlow, of Woolwich, published in an octavo volume the squares, cubes, square-roots, cube-roots, and reciprocals of all numbers from 1 to 1,000—a table of the first ten powers from 1 to 100, and a table of the fourth and fifth powers of all numbers from 100 to 1,000.

To a still greater extent were similar tables prepared on the continent. In France, in the year 1785, was published an octavo volume of the tables of squares, cubes, square-roots, and cube-roots of all numbers from 1 to 10,000; and in 1824 from 1,000 times to 100. A larger table of squares than at that time existing was published in Hanover in 1810: a larger still in Leipsic in 1812; a more perfect one at Berlin in 1825; and a similar table at Ghent in 1827.

This class of tables involves only the arithmetical dependence of abstract numbers upon each other. To express peculiar modes of quantity—such as angular, linear, superficial, and solid magnitudes—a larger number of computations are required. Volumes without number of these tables also have been computed and published at infinite labor and expense. Then come tables of a special nature, of importance not inferior, of labor more exacting—tables of interest, discount, and exchange; tables of annuities and life insurance, and tables of rates in general commerce. And then, above all others, tables of astronomy, the multiplicity and complexity of which it is impossible to describe, and the importance of which, in the kindred art of navigation, it would be difficult to over-estimate. The safety of the tens of thousands of ships upon the ocean, the accuracy of coast surveys, the exact position of light-houses, the track of every shore from headland to headland, the latitude and longitude of mid-sea islands, the course and motion of currents, direction and speed of winds, bearing and distance of mountains, and, in short, everything which constitutes the chief element of international commerce in modern times, depends upon the fullness and accuracy of logarithmic tables.

Inadequate as is the notion of the *importance* of these tables that has been conveyed, still more inadequate must be any notice of their errors. The expedients resorted to for even a limited degree of accuracy have been almost innumerable. The first French Republic, aspiring to lead the nations in science, undertook, through its mathematicians, by a division of labor so admirable that it seemed impossible errors should be committed, or, if committed, remain undetected, to produce a system of logarithmic and trigonometric tables so accurate that it should form a monument of the kind more imposing than had ever been conceived. The attempt failed, for one singular reason among others, that the computers who committed the fewest errors were those who understood nothing beyond the process of addition. Dr. Lardner discovered in forty tables, taken at random, no less than 3,700 *errata*. In the Nautical Almanac Mr. Baily detected more than 500 errors of calculation. The "tables requisite to

be used with the Nautical Ephemeris for finding latitude and longitude at sea," computed, revised, and rerevised with the utmost care, under direction of the British board of longitude, and published by the government, was found to contain above a thousand errors. The tables of the distances of the moon from certain fixed stars, published by the same board, is followed by 1,100 *errata*, and these themselves contained so many errors as to make *errata* upon *errata* necessary. For the special use of the national survey of Ireland, the logarithmic tables, most carefully prepared, were found to contain six errors, and these, by comparison, were found to exist not only in tables published during more than two hundred years in Paris and Gouda, Avignon and Berlin, Florence and London, but also in a set printed in China, in Chinese characters, and purporting to be original calculations. In fact, absolute correctness in logarithmic tables has never been attained. Year after year, through eight generations of mathematicians, one set has followed another to correct its predecessor. Even the last claims but approximate accuracy. Precautions, comparisons, revisions, and alterations from computers to computers, make advances *only toward* an end that is never absolutely reached. And no wonder. We need but to consider the nature of a numerical table, where a thousand pages are covered with figures alone, where neither note nor comment, letters of the alphabet, nor rules of syntax, are permitted to intrude, to understand that the law of chance is on the side of error, and that for one mistake that may happen to be detected a score may escape unnoticed.

Besides the errors incidental to computation, there are those of *transscribing* for the press, and of *composition* into print. Nor does the liability to error stop even here, errors being often produced in the process of printing. A remarkable instance of this occurs in one of the six errors of the Irish Survey Tables, just mentioned. The last five figures of two successive numbers of a logarithmic table were

35875
10436

Both were erroneous. The "8" in the upper line should be "4," and the "4" in the lower line should be "8." It is evident that the types, as first composed, were correct—that two of them, "4" and "8," became loose, adhered to the inking ball, and were drawn out—and that the pressman in replacing transposed them. And this inadvertent error in Blacq's tables of 1628, traveled over three continents, and, with more or less of mischief, remained undetected for two hundred years.

Numerical correctness in logarithmic tables, is then, and has ever been, the great *desideratum*. This Mr. Babbage proposed to attain by machinery; to calculate the tables unerringly, as if by a law of nature, and by the same law to reduce them as unerringly to type. Thus was the single purpose of the difference engine No. 1.

The difference engine No. 1 was only partially competed. Confided to the care of King's College, it remained for twenty years in the mu-

seum at Somerset House. In 1862 it was exhibited at the Great Industrial Exhibition, since which time it has been stored at the South Kensington Museum. The finished portion of the engine showed itself capable of computing any table whose third difference is constant and less than 1,000; while at the same time it showed the position in the table of each tabular number. In Mr. Babbage's own words:

"1st. The portion of the machine exhibited can calculate any table whose third difference is constant and less than 10.

"2d. It can show how much more rapidly astronomical tables can be calculated in any engine in which there is no constant difference.

"3d. It can be employed to illustrate those singular laws which might continue to be produced through ages, and yet after an enormous interval of time change into other different laws; each again to exist for ages, and then to be superseded by new laws."

It will be borne in mind that all work upon difference engine No. 1 was stopped in the early part of the year 1833. At the general meeting of the Royal Academy at Brussels in May, 1835, a letter received from Mr. Babbage was read announcing that he had been engaged for six months in making drawings of a new calculating machine of far greater power. "I am myself astonished," he wrote, "at the power I have been enabled to give to this machine: a year ago I should not have believed this result possible. The machine is intended to contain a hundred variables, each consisting of twenty-five figures; it will reduce to tables almost all equations of finite differences; it will calculate a thousand values (of *e. g.* $a\ b\ c\ d$ by the formula $p = \left.\frac{\sqrt{a+b}}{c\ a}\right)$ print them, and reduce them to zero, and will then ring a bell to give notice that a new set of constants must be inserted." "When there exists," he continues, "a relation between any number of successive co-efficients of a series, provided it can be expressed, the machine will calculate them and make their terms known in succession; and it may afterward be disposed so as to find the value of the series for all the values of the variable."

This was the first announcement to the scientific world of a machine, capable of executing not merely arithmetical calculations, but even those of analysis when the laws are known. It was, in fact, the analytical engine, never destined to be completed by its inventor in actual fact, but so perfect in its drawings, so clear in its descriptions, so certain in its sequences, and so logical in all its principles, that, to the minds of men capable of comprehending the details, it became as certainly the realization of a gigantic idea as if it had been doing its work in their presence. If it be asked, how such a machine could of itself, without recourse to thought, assume the successive dispositions necessary, Mr. Babbage answers that Jacquard solved the problem when he invented his loom.

In the manufacture of brocade there are two species of threads, the

one longitudinal, which is the *warp*, the other transverse, which is the *woof*.

Of course the analytical engine could not originate. It would have always been the servant—never the master. It could have done whatever its inventor *knew how to order it to do*. No more. It assisted—marvelously indeed, but it only assisted—in making the *known* available. It could have *followed* analysis, never *anticipated* it. But had it been constructed, it would have achieved three *desiderata* of science—*economy of time, economy of intelligence, rigid accuracy*. It would have made observations fertile that are now barren for lack of computing powers; it would have saved time for contemplation that is now wasted in arid calculations by men of genius, and it would have made *certain* arithmetical numbers, without the aid of which the veil that envelopes the mysteries of nature can never be raised.

As illustrative of the estimate put upon the operations of the analytical machine, it may not be inappropriate to quote here Mr. Babbage's own remarks: "An excellent friend of mine," he writes, "the late Professor MacCullagh, of Dublin, was discussing with me the various powers of the analytical engine. After a long conversation he inquired what the machine could do, if, in the midst of algebraic operations, it was required to perform logarithmic or trigonometric operations. My answer was, that whenever the analytical engine should exist, all the developments of formula would be directed by this condition, that the machine should be able to compute their numerical value in the shortest possible time; I then added that if this answer was not satisfactory, I had provided means by which, with equal accuracy, it might compute by logarithmic or other tables.

"I explained that the tables to be used must, of course, be computed and punched on cards by the machine, in which case they would undoubtedly be correct. I then added, that when the machine wanted a tabular number it would ring a bell and then stop itself. On this the attendant would look at a certain part of the machine and find that it wanted the logarithm of a given number, say of 2303; the attendant would then go to the drawer, take the required logarithmic-card, and place it on the machine. Upon this the engine would first ascertain whether the assistant had or had not given it the correct logarithm of the number; if so, it would use it and continue its work. But if the engine found the attendant had given it a wrong logarithm, it would then ring a louder bell and stop itself. On the attendant again examining the engine, he would observe the words, WRONG TABULAR NUMBER, and then discover that he really had given the wrong logarithm, and of course would have to replace it by the right one."

As between the two engines, the difference and the analytical, their powers and principles of construction, the capabilities of the latter would have been immeasurably the more extensive. They hold to each other, in fact, the same relationship that analysis holds to arithmetic. The dif-

ference engine was intended to effect but one particular series of operations. It was not the *general* expression even of *one particular* function, much less of any and all possible functions of all degrees of generality. Indeed, it could do nothing but add. It certainly performed the processes of subtraction, multiplication, and division; but then only so far as these could be reduced to a series of additions. The analytical machine, on the contrary, would have been able to add or subtract, multiply or divide—it could have done either and all with equal facility—and it would have performed these operations directly in each case without the aid of any of the other three. This fact implies everything. The one engine merely tabulated but never developed; the other both tabulated and developed.

Mr. Babbage's third invention, which he named "difference engine, No. 2," need not be dwelt upon here. It was never built. Its drawings even were never quite completed. As an entity it had no existence out of his own mind. In laboring to perfect the analytical machine he discovered the means of simplifying and expediting the mechanical processes of difference engine No. 1. The Earl of Rosse, who was greatly interested in the application of mechanism to purposes of calculation, and who was well acquainted with the drawings and notations of the second difference engine so far as made, proposed that Mr. Babbage should perfect and give them to the government, upon condition that they would undertake to construct it. To this, with some reluctance, he consented. It was then proposed to the Earl of Derby, he being prime minister, that the government should apply to the president of the Institution of Civil Engineers to ascertain—

1st. Whether it was possible from Mr. Babbage's drawings and notations to make an estimate of the cost of constructing the machine.

2d. In case this question was answered in the affirmative, then could a mechanical engineer be found who would undertake to construct it, and at what expense.

It was explained to Lord Derby that the cessation of work upon the first difference engine was owing to no fault of Mr. Babbage; that, being new in design and construction, and requiring the utmost mechanical skill for its execution, it had necessarily been costly; that the necessity of constructing and, in many instances, inventing tools and machinery of great complexity for forming with requisite precision parts of the apparatus dissimilar to any used in ordinary mechanical works, had produced unavoidable delays, and that the foremost men of practical science all over Europe who were acquainted with the facts, so far from being surprised at the time and expense that had been required to bring the engine to its then present state, felt much more disposed to wonder that it had been possible to accomplish so much. "If this work," Mr. Babbage wrote to the minister, "upon which I have bestowed so much time and thought were a mere triumph over mechanical difficulties, or simply curious, or if the execution of such engines were of doubtful practica-

bility or utility, some justification might be found for the course which has been taken; but I venture to assert that no mathematician who has a reputation to lose will ever *publicly* express an opinion that such a machine would be useless if made, and that no man distinguished as a civil engineer will venture to declare the construction of such machinery impracticable."

It seemed now (1852) as if there were a probability that government would order a resumption of the work. The Earl of Derby was a man of large gifts and extended views, and his chancellor of the exchequer, himself the son of a philosopher, was known as widely almost by his philosophic sentiments as by his great powers of debate. The country was at peace. The first exhibition of the whole world's industry had by its marvelous success the previous year given a new impulse to the arts. Politics, indeed, ran high, but in every other aspect there was encouragement. The Royal Society; the Society of Civil Engineers; the Royal Academy of Sciences, at Brussels; the principal philosophical mechanists of the three kingdoms, led by the Earl of Rosse and Sir Benjamin Hawes; the astronomical observers following in the bold path opened by Sir John Herschel; and Prince Albert, the most accomplished, as he was the most judicious, of thinking men; together with Plana, Menabria, MacCullagh, Mosotti, Plantamour, Dr. Lardner, and Lady Lovelace—this last an example, almost equal to that of Mrs. Somerville, of the power sometimes possessed by the female mind in dealing with abstract truths—all gave the weight of their opinion in favor of the difference engine, when completed, as fully adequate to the attainment of the objects proposed by the inventor. "No enterprise," said the president of the Royal Society, when reciting the history of the engine at their anniversary in 1854—"no enterprise could have had its beginning under more auspicious circumstances. The government had taken the initiative; they had called for advice, and the adviser was the highest scientific authority in this country—your council guided by such men as Derby, Wollaston, and Herschel. By your council the undertaking was inaugurated; by your council it was watched over in its progress. That the first great effort to employ the powers of calculating mechanism, in aid of the human intellect should have been suffered in this great country to expire fruitless because there was no tangible evidence of immediate profit, as a British subject I deeply regret, and as a fellow my regret is accompanied with feelings of bitter disappointment. Where a question has once been disposed of, succeeding governments rarely re-open it; still, I thought I should not be doing my duty if I did not take some opportunity of bringing the facts once more before government."

This was accordingly done. It was shown that mechanical engineering, tools, trained workmen, the founder's art; and screw-cutting machines, had made such progress during the years the difference-engine had been laid aside that it was probable persons could be found willing

to complete it for a specific sum. Never had a ministry a nobler opportunity to illustrate its history by the encouragement of science. It was, however, all in vain. Art was weighed against gold, and the former, touched the beam. The chancellor of the exchequer, to whom Lord Derby referred the question, pronounced the project as—

"1. Indefinitely expensive.

"2. The ultimate success problematical.

"3. The expenditure utterly incapable of being calculated."

"This Herostratus of science," Mr. Babbage characteristically remarks, "if he escape oblivion, will be linked with the destroyer of the Ephesian Temple."

It would be unjust to the memory of the great philosophical mechanist were no reference made to the incidental invention of a mechanical notation which Mr. Babbage explained in a paper read before the Royal Society in 1826. Dr. Lardner entitled it a discovery of "the utmost practical value," and it has long been adopted as a topic of lectures in institutions all over Europe for the instruction of civil engineers. It came up in this wise: Memory has its limit. There cannot be borne in mind a great variety of motions propagated simultaneously through complicated trains of mechanism. Incompatible motions will encounter each other. The memory can neither guard against nor correct them. Some expedient which at a glance could exhibit what every moving piece in the machinery was doing at each instant was needed. Necessity, the mother of invention, suggested to Mr. Babbage a system of signs, by which the mechanist, simply moving his finger along a certain line, could follow out the motion of every piece from effect to cause until he arrived at the prime mover. The same sign which indicated the *source* of motion indicated also its *species*. It also divided time into parts, showing what was being done by a machine at any moment. By this means the contriver understood the situation *instanter*, saw as if by intuition the fault, and discovered the *niche* in which to place the movement required. It also enabled the inventor to dismiss from his mind the arrangement of the mechanism. Like algebraic signs, it reduced wheels and valves, rods and levers, to an equation. In fact, what algebra is to arithmetic Mr. Babbage's notation was to mechanism.

During the construction of some parts of the calculating machinery a question arose as to the best method of producing and arranging a certain series of motions necessary to calculate and print a number. Mr. Babbage, with his assistant, an eminent practical engineer, had so arranged these motions that they might be performed by twelve revolutions of the principal axis. It was desirable there should be less. To this end each put himself to work, the engineer to a study of the complicated working machinery, the inventor to a consideration of his notation symbols. After a short time, by some transposition of these, the latter succeeded in producing the series by *eight* turns of the axis. Pushing his inquiries still further, he proceeded to ascertain whether

his scheme of symbols did not admit of a still more compact arrangement, and whether eight revolutions were not needless waste of power. The question was exceedingly abstruse. Finding every effort to keep in mind the order and arrangement of wheels and pulleys, levers and shafts, claws and bolts, so as to suggest any improved arrangement, the engineer completely broke down. Mr. Babbage, however, with scarcely any mental exertion, and merely by sliding a bit of ruled pasteboard up and down his plan in search of vacant places, contrived at length to reduce the eight motions to six, to five, and to three. This application of an almost metaphysical system of abstract signs, by which the motion of the hand alternately performs the office of the mind and practical mechanics, to the construction of a complicated engine, is regarded by many eminent engineers as the most wonderful and useful discovery the great inventor ever made.

Although no one of the principal inventions of the philosophic mechanist has ever been completed, and though his marvelously comprehensive thoughts of what machinery, working on the border land of intellect, might be made to accomplish would seem to have passed from the world without good, yet his work was not in vain. Hundreds of mechanical appliances in the factories and workshops of Europe and America, scores of ingenious expedients in mining and architecture, the construction of bridges and boring of tunnels, and a world of tools by which labor is benefited and the arts improved—all the overflowings of a mind so rich that its very waste became valuable to utilize—came from Charles Babbage. He more, perhaps, than any man who ever lived, narrowed the chasm that from earliest ages has separated science and practical mechanics.

This memoir has thus far treated its subject as a mathematician and philosophical mechanist. He was both, in a degree that made his name famous. But he was more than this. As a scientific man, keeping himself abreast with the progress of modern discovery; as a man of intellect, accepting, analyzing, and suggesting thought that is emancipating mind from old traditions; and as a man of his time, the associate for more than half a century of statesmen and poets, chemists, and geographers, engineers, and philologists, he is worthy of notice. Upon whatever he spoke or wrote he was always perspicuous. Language was to him pre-eminently the embodiment of ideas. Logical sequence was the one essential element of his train of thinking. His estimate of men was formed less from what they were than from what they did. He was neither tuft-hunter nor cynic. Faults his character possessed, grievous and ridiculous, perchance, when viewed in certain lights, but they were never inconsistent with his independent manliness, nor derogatory to his elevated philosophy. He knew his own worth; asserted his rightful claims; kept an unquailing aspect in his long single-hand fight in behalf of his inventions with purblind rulers; victorious never, but never vanquished; heroic in most that he said and all that he did;

above ordinary stature; and, saving perhaps the acceptance of certain rules of obedience to law, without which no one can wisely govern himself, played a part in the drama of life that will not be soon forgotten.

It is proposed now to speak of Charles Babbage in the two characters of an *observer of his time* and as a *contributor to knowledge.* In each, as the most certain way to reach the end in view, we shall quote without restriction or further acknowledgment from his own writings:

"My engine," he said to some scientific friends after a friendly breakfast, "will count the natural numbers as far as the millionth term. It will then commence a new series, following a different law. This it suddenly abandons and calculates another series by another law. This again is followed by another, and still another. It may go on throughout all time. An observer, seeing a new law coming at certain periods, and going out at others, might find in the mechanism a parallel to the laws of life. That all men die is the result of a vast induction of instances. That one or more men at given times shall be restored to life, may be as much a consequence of the law of existence appointed for man at his creation, as the appearance and re-appearance of the isolated cases of apparent exception in the arithmetical machine. Miracles, therefore, may not be the breach of established laws, but the very circumstances that indicate the existence of higher laws, which, at appointed times produce the preintended results.

"For example, the analytical engine might be so set that at definite periods, known only to its maker, a certain lever might become movable during the calculations then making. The consequence of moving it might be to cause the then existing law to be violated for one or more times, after which the original law would resume its reign. Of course, the maker of the calculating engine might confide this fact to the person using it, who would thus be gifted with the power of prophecy if he foretold the event, or of working a miracle at the proper time if he withheld his knowledge from those around until the moment of its taking place. Such is the analogy between the construction of machinery to calculate, and the occurrence of miracles. A further illustration may be taken from geometry; curves are represented by equations. In certain curves there are portions, such as ovals, disconnected from the rest of the curve. By properly assigning the values of the constants, these ovals may be reduced to single points. These singular points may exist upon a branch of a curve, or may be entirely isolated from it; yet these points fulfill by their position the law of the curve as perfectly as any of those which, by their juxtaposition and continuity, form any of its branches."

"Miracles," Mr. Babbage adds, "are not therefore the breach of established laws, but the very circumstances that indicate the existence of far higher laws which, at the appointed times, produce their preintended results."

Now whatever may be thought of the conclusiveness of this reasoning,

its originality is obvious, and its ingenuity undeniable. That it was satisfactory to a mind whose reach was as wide and whose logic as consecutive as that of Charles Babbage, is sufficient to demand for it fair consideration. He evidently believed it; urged it upon other minds upon the same level with his own, and received no answers that detected in it a fallacy or showed it to be a sophism.

There is surpassing interest in watching the workings of a great mind in *honest* search after truth. There are no volumes of the fathers; no sermons of Laurin or Bossuet; no essays of Fénelon or Pascal; no personal narrative of Arnauld, Françoise de Sales, de Rancé, or of the saints of Port Royal; no memoirs of the pietists of France, or martyrs of England; no lives of foreign missionaries, Protestant or Catholic, who gave their all, even to death, to propagate what to them was Divine that in our apprehension can confine the attention or challenge the judgment of a sincere, intelligent inquirer after truth, like the thirtieth chapter in the "Passages from the Life of a Philosopher." One sees in it no favorite opinion to be defended; no peculiar error to be denounced; no class, no creed, no caste to be built up; no prejudice to be favored nor tradition exempted from trial; nothing, in fact, but the record of the thoughts of a great mind in honest pursuit of truth. It would be marred by quotations, and its life deadened by condensation; though it does not traverse the ground of more modern skepticism, and deals only with the old positions of the encyclopedists and Hume, it assumes a position in regard to Divine revelation which, if not impregnable, has never yet been overturned.

We cannot easily resist the temptation to quote a few of his clear and vigorous remarks from the chapter in question. Speaking of an examination of the Creator's works as one of the sources of our knowledge of His existence, Babbage says:

"Unlike transmitted testimony, which is weakened at every stage, its evidence derives confirmation from the progress of the individual as well as from the advancement of the knowledge of the race.

"Almost all thinking men who have studied the laws which govern the animate and inanimate world around us, agree that the belief in the existence of one Supreme Creator, possessed of infinite wisdom and power, is open to far less difficulties than the supposition of the absence of any cause, or the existence of a plurality of causes.

"In the works of the Creator, ever open to our examination, we possess a firm basis on which to raise the superstructure of an enlightened creed. The more man inquires into the laws which regulate the material universe, the more he is convinced that all its varied forms arise from the action of a few simple principles. These principles themselves converge, with accelerating force, toward some still more comprehensive law to which all matter seems to be submitted. Simple as that law may possibly be, it must be remembered that it is only one among an infinite number of simple laws; that each of these laws has consequences

at least as extensive as the existing one, and, therefore, that the Creator who selected the present law must have foreseen the consequences of all other laws.

"The works of the Creator, ever present to our senses, give a living and perpetual testimony of his wisdom and goodness far surpassing any evidence transmitted through human testimony. The testimony of men becomes fainter at every stage of transmission, while each new inquiry into the works of the Almighty gives to us more exalted views of his wisdom, his goodness, and his power."

The true value of the Christian religion in Babbage's estimation rested not upon speculative views of the Creator, which must necessarily be different in each individual, according to the extent of the finite being who employs his own feeble powers in contemplating the infinite, but rather upon those doctrines of kindness and benevolence which that religion claims and enforces, not merely in favor of man himself but of every creature susceptible of pain or of happiness.

There is something exceedingly refreshing in the original views Mr. Baggage takes of every subject that comes within the scope of his vision. His autobiography—for such in spite of his disclaimer it really is—has the interest of a romance. He is never dull, never tiresome, never cloudy. His style is clear as limpid water and natural as a running brook. He possesses a rich fund of humor, which flecks and dapples even his mathematical descriptions like sunshine falling through foliage.

"A curious reflection" he says in the chapter we do not willingly leave, "presents itself, when we meditate upon a state of rewards and punishments in a future life. We must possess the memory of what we did during our existence upon this earth in order to give them those characteristics. In fact, memory seems to be the only faculty which must, of necessity, be preserved in order to render a future state possible.

"If memory be absolutely destroyed, our personal identity is lost.

"Further reflection suggests that in a future state we may, as it were, awake to the recollection that, previously to this our present life, we existed in some former state, possibly in many former ones, and that the then state of existence may have been the consequences of our conduct in those former stages.

"It would be a very interesting research if naturalists could devise any means of showing that the dragon fly, in its three stages of a grub beneath the soil, an animal living in the water, and that of a flying insect, had in the last stage any memory of its existence in its first.

"Another question connected with this subject offers still greater difficulty. Man possesses five sources of knowledge through his senses: He proudly thinks himself the highest work of the Almighty Architect, but it is quite *possible* that he may be the very lowest. If other animals possess senses of a different nature from ours, it can scarcely be possible

that we could ever be aware of the fact. Yet those animals, having other sources of information and of pleasure, might, though despised by us, yet enjoy a corporeal as well as intellectual existence far higher than our own."

Mr. Babbage's autobiography, relating isolated facts, which, with a sort of indifference to the estimate history might put upon his character—strongly in contrast with even the best class of journals and diaries, say, Sir Walter Scott's, or Dr. Chalmer's, or Edward Payson's, or Missionary Judson's, as if while it was necessary that *they* should take care of their *post-mortem* fame *his* possessed the vitality to care for itself—are arranged without order of time or similarity of subject, after all divides itself very naturally into the two branches of personal recollections and personal experiences. He remembers Wollaston, Rogers, and Sir Humphrey Davy, and gives pen-outlines of their characters as vivid and living as the portraits of Duow. He has discussed mathematics with Laplace, compared analysis with Fourier, exhibited and explained his inventions to Biot, and lived on terms of intimacy with Humboldt. He was the frequent companion of the Duke of Wellington; was the associate of various branches of the Bonaparte family; was the friend of Mosotti, Menabria, and Prince Albert, and throughout life, from collegiate competitions to the mutual respect of mature years, held firmly as his friend the younger Herschel. Of all these his notes are pictures, unequalled even by the descriptions which Boswell gives of the associates of the great lexicographer.

It is the same with his experiences. He risks drowning by water and baking by fire, loss of life by railway speed and loss of reputation by picking locks, character in exploring the secrets of theatrical displays, and purse in traversing the haunts of St. Giles. His thirst for knowledge knew no bounds. Into an electioneering contest he entered with the same indomitable energy that he pursued a mathematical calculus. The same keen avidity that detected a logarithmic error was applied to suppressing a street nuisance. He vitalized whatever he touched. If life gives beauty it might be more truly said of Charles Babbage than of most men of mark, *Nihil tetigit quod non ornavit.* In fact there was no secret of nature he hesitated to explore, no enigma of the sphynx which he was afraid to question. Impulsiveness, want of patience, and hatred of shams have indeed left many of his investigations partial and fragmentary, but about every one of them there is rich compensation in striking aphorisms, profound observations, wisdom applicable to human need, and wit available for its enjoyment. He says of himself:

"I have always carefully watched the exercise of my own faculties, and I have always endeavored to collect from the light reflected by other minds some explanation of the question.

"I think one of my most important guiding principles has been this: That every moment of my waking hours has always been occupied by

some train of inquiry. In far the largest number of instances the subject might be trivial, but still work of inquiry was always going on.

"The difficulty consisted in adapting the work to the state of the body. The necessary training was difficult. Whenever at night I found myself sleepless and wished to sleep, I took a subject for examination that required little mental effort, and which also had little dependence on worldly affairs by its success or failure.

"On the other hand, when I wanted to concentrate my whole mind upon an important subject, I studied during the day all the minor accessories and after 2 o'clock in the morning I found that repose which the nuisances of the London streets only allow from that hour until 6 in the morning.

"At first I had many a sleepless night before I could thus train myself.

"I believe my early perception of the immense power of signs in aiding the reasoning faculty contributed much to whatever success I may have had. Probably a still more important element was the intimate conviction I possessed that the highest object a reasonable being could pursue was to endeavor to discover those laws of mind by which man's intellect passes from the known to the discovery of the unknown."

In perusing the writings of Mr. Babbage, one is constantly struck with the philosophical nature of his mind. His style is not only pregnant with thought, but, like Montaigne's, is perpetually shaping itself into apothegms. "Men," he writes, when managing an election contest, "will always give themselves tenfold more trouble to crush a man obnoxious to their hatred, than they will take to serve their most favored ally."

Again, speaking of Dr. Lardner, who had candidly admitted that some of those doctrines he had once supported further information had shown him were erroneous, our author says, "Nothing is more injurious to the progress of truth than to reproach any man who honestly admits he has been in error."

In order to put down street organ-grinders, with whom he had lifelong quarrels, he proposes to himself to act upon this principle: "*to make it more unprofitable to the offender to do the wrong than the right.*"

"It requires considerable training to become an accurate witness of facts. No two persons, however well trained, ever express in the same form of words the series of facts they have both observed."

"Once, at a large dinner party, Mr. Rogers, author of 'Italy' and other poems, was speaking of an inconvenience arising from the custom, then commencing, of having windows formed of one large sheet of glass. He said that a short time ago he sat at dinner with his back to one of these single panes of plate-glass; *it appeared to him that the window was wide open, and such was the force of the imagination that he actually caught cold.*

"It so happened that I was sitting just opposite to the poet. Hearing this remark, I immediately said, Dear me, how odd it is, Mr. Rogers,

that you and I should make such a very different use of the faculty of imagination. When I go to the house of a friend in the country and unexpectedly remain for the night, having no night-cap I should naturally catch cold. *But by tying a piece of pack-thread tightly round my head, I go to sleep imagining that I have a night cap on; consequently I catch no cold at all.*"

"I was once asked by an astute and sarcastic magistrate, whether I seriously believed that a man's brain would be injured by listening to an organ. My reply was, *Certainly not, for the obvious reason that no man having brains ever listened to street musicians.*"

These fragmentary quotations, however, scarcely do Mr. Babbage justice. Let us allow him to tell one of the many experiences of his life in his own way.

Under the head of "Hints for travelers," in his "Passages from the life of a philosopher," Mr. Babbage says:

"A man may, without being a proficient in any science, often make himself useful to those who are most instructed. However limited the path he may himself pursue, he will insensibly acquire other information in return for that which he can communicate. I will illustrate this by one of my own pursuits. I possess the smallest possible acquaintance with the vast fields of animal life, but at an early period I was struck by the numerical regularity of the pulsations and the breathings. It appeared to me that there must exist some relation between these two functions. Accordingly I took every opportunity of counting the numbers of the pulsations and the breathings of various animals. The pig fair at Pavia and the book fair at Leipsic equally placed before me menageries in which I could collect such facts. Every zoological collection of animals which I visited thus became to me a source of facts relating to that subject. This led me at another period to generalize the subject of inquiry, and to print a skeleton form for the constants of the class mammalia. It was reprinted by the British Association at Cambridge in 1833, and also at Brussels in the *Travaux du Congres Général de Statisque* in 1853.

"One of the most useful accomplishments for a philosophical traveler I learned from a workman who taught me how to punch a hole in a plate of glass. The process is simple. Two center-punches, a hammer, an ordinary bench-vise, and an old file, are all the tools required. Having decided upon the part of the glass, scratch a cross (×) upon the spot with the point of an old file, turn the glass over and scratch the same on the other side corresponding. Fix one of the small center-punches with its point upward in the vise. Let an assistant hold the glass with its scratched point (×) resting upon the point of the punch. Take the other punch, place its point in the center of the upper scratch, hit it very slightly twice or thrice, turn the glass two or three times, repeating the slight blows, and the hole is formed.

"The principles of this are, that glass is a material breaking in every

direction with a conchoidal fracture, and that the vibrations which would have caused cracking are checked by the support of the fixed center-punch.

"In the year 1825, during a visit to Devonport, I had apartments in the house of a glazier, of whom I inquired one day if he knew this secret. He answered that he did not, and expressed great curiosity to see it done. Finding that at a short distance there was a blacksmith, we went to his shop, and selecting from his rough tools the center-punches and the hammer, I executed the whole process.

"On the eve of my departure I asked for my landlord's account, which was sent up correct except the omission of charge for apartments. I added the eight guineas for my lodgings; and the next morning, having placed the total amount upon the bill, I sent for my host in order to pay him, remarking that he had omitted the principal article of his account, which I had inserted.

"He replied that he had intentionally omitted the lodgings, as he could not think of taking payment for them from a gentleman who had done him so great service. Quite unconscious of having rendered him any service, I asked him to explain. He replied that he had the contract for the supply and repair of the lamps of Devonport, and that the art in which I had instructed him would save him more than twenty pounds a year. I found some difficulty in prevailing on my grateful landlord to accept what was justly his due."

Scarcely at the risk of being tedious—which no passages in the life of this extraordinary man can ever be—but at the greater risk of space which must be devoted to his contributions to knowledge, we cannot forbear a single quotation further, which, like a dash from the brush of Rubens, depicts the multifariousness of his character:

"While I was preparing materials for the 'Economy of manufactures,'" he writes, "I had occasion frequently to travel through our mining and manufacturing districts. On these occasions I found the travelers' inn or travelers' room was usually the best adapted to my purpose, both in regard to economy and to information. As my inquiries had a wide range, I found ample assistance in carrying them on. Nobody doubted that I was one of the craft; but opinions were widely different as to the department in which I practiced my vocation.

"In one of my tours I passed a very agreeable week at the Commercial Hotel in Sheffield. One evening we sat up after supper much later than is usual, discussing a variety of commercial subjects.

"When I came down rather late to breakfast I found only one of my acquaintances of the previous evening remaining. He remarked that we had had a very agreeable party last night, to which I assented. He referred to the intelligent remarks of some of our party, and then added that when I left them they began to talk about me. I merely added that I felt quite safe in their hands, but should be glad to profit by their remarks. It appeared, when I retired for the night, that they debated

about what trade I traveled for. 'The tall gentleman in the corner,' said my informant, 'maintained that you were in the hardware line, while the fat gentleman, who sat next you at supper, was quite sure that you were in the spirit trade. Another of the party declared that they were both mistaken; he said he had met you before, and that you were traveling for a great iron-master.' 'Well,' said I, 'you, I presume, knew my vocation better than our friends.' 'Yes,' said my informant, 'I knew perfectly well that you were in the Nottingham lace trade!'"

In the year 1828 Mr. Babbage was nominated to the Lucasian professorship of mathematics in his old university, occupying in that capacity a chair which had once been held by no less a man than Sir Isaac Newton. This chair he held during eleven years. It was while holding this professorship, at the general election of November, 1832, which followed on the passage of the first reform bill, that he was put forward as a candidate for the representation of Finsbury in Parliament. He stood in the advanced liberal interest as a supporter not only of parliamentary, financial, and fiscal reform, but of the ballot, triennial parliaments, and the abolition of all sinecure posts and offices. But the electors did not care to choose a philosopher; so he was unsuccessful, and never again wooed the suffrages of any constituency.

Mr. Babbage was the author of published works to the extent of some eighty papers. A full list of these, however, would not interest or edify the reader. Perhaps the best known of them all is what he styled the *Ninth Bridgewater Treatise*, (which it was not,) a work designed at once to refute the doctrine, supposed to be implied in the first volume of that learned series, that an ardent devotion to mathematical studies is unfavorable to a real religious faith; and also to adduce specimens of the defensive aid which the science of numbers may give to the evidences of Christianity, if that science be studied in a proper spirit. As compared with the eight treatises written by Chalmers, Whewell, Sir Charles Bell, Dr. Buckland, and others, so far from discrediting its supposititious name, it has probably been more generally read than any work of the series.

Mr. Babbage's contributions to political economy were both incidental and direct. The tendency of his mind, upon whatever it was engaged, was toward the practical. There is scarcely one of his works—nay, there is hardly one of the various employments in which he engaged himself with his whole soul during his long life—that in its ultimate reach does not lay hold of the industrial condition of mankind. Keen in investigation, acute in analysis, subtle in detection of error, and pre-eminently logical in conclusions, no matter how purely intellectual may be the laboratory of his workings, the experiments he makes and the outlooks in which he indulges have for their end invariably the material benefit of the working classes. Whether it be the solution of "problems relating to the calculus of functions" or relating to the "knight's move in chess;" whether the "determination of the general term of a new class

of infinite series" or the "application of machinery to the computation of mathematical tables," the "measurement of heights" or the "improvements of diving-bells," "proportion of letters occurring in various languages" or "observations on the Temple of Serapis," "thoughts on the principles of taxation" or "statistics of light-houses," his purpose in every essay is practical good. He enlivens the dry subject of political economy by the most interesting and pertinent anecdotes; draws the attention of engine-drivers and stokers to his abstruse discussions of curves and gauges on railways by maxims and rules that are of constant use; discusses the subject of Greenwich time-signals with a variety of illustrations that makes it attractive to every ship-master; mingles his philosophical theories on occulting lights with narratives of observations and experiences that amuse and instruct the most ordinary minds; and treats the vexed question of glaciers with a liveliness and perspicuity which interest if they do not convince.

The reader will judge whether we have overestimated or misunderstood the real characteristics of Mr. Babbage's mind from the examples we now propose to give from some of his contributions to knowledge.

Mr. Babbage was one of the oldest members of the Royal Society at the time of his death in October of last year. He was also, more than half a century ago, one of the founders of the Astronomical Society, and he and Sir John Herschel were the last survivors of those founders. He was also an active and zealous member of many of the leading learned societies of London and Edinburg, and, in former years at least, an extensive contributor to their published transactions. His last important publication was the amusing and only too characteristic autobiographical work from which we have freely quoted—"Passages from the Life of a Philosopher."

There were methods of action—qualities they might perhaps be more properly called—in the mind of Charles Babbage that recall to the philosophical peruser of his works in the exact sciences traits not dissimilar in kind, however distinct in degree, to those possessed by that most original of all thinkers, Sir Isaac Newton. He possessed in common with Newton extraordinary powers of intellectual introversion. What he desired to accomplish he *thought out.* His mind, like a photographic plate, was cleansed by a continued force of will to think rightly, and when cleansed received its impressions from the light of truth. Not only his contributions to knowledge and his complex and intricate calculating-machines, but the scores of lesser inventions which he produced from time to time, are illustrative of this. Like Newton, he first pondered his facts, illuminated them by persistent thought, and then proceeded to the principles on which these facts depend.

Pestalozzi, the Italian philanthropist, after a long life spent in works of benevolence, came at last to the conclusion that no man could be much helped or hindered by any one but himself. The remark is applicable to Charles Babbage more than to most persons. He both made

and marred his own fortune. There was not a place which he ever sought (the Lucasian chair he did not seek) that he gained. He aspired to the professorship of mathematics at the East India College at Harleyburgh; to Playfair's chair at Edinburgh; to a seat at the Board of Longitude; to the mastership of the mint; and to the office of registrar-general of births and deaths—and failed in all. On the other hand, there was not an invention connected with his name—and in mathematical mechanics he ranks among the foremost the world ever produced—which, in the opinion of the best-disciplined minds of his day, he could not have perfected had sufficient pecuniary means been at his command. Unfortunately, he measured everything by his own unaided impressions, and judged himself by others instead of judging others by himself. To rest all claim to greatness on self-assertion rather than self-denial, though it may have made the heroes of the classic ages, cannot but be a grave fault in the conduct of any modern life. Still, he bore his disappointments bravely, possessed his intellect undimmed up to the verge of his fourth-score year, made his old age a lesson—not unwisely at any time enforced—of the philosophy with which the rest of death may be awaited, and was to the last ready to contemplate calmly in his own case what arose to the thought of Antony—

> I have been sitting longer at life's feast
> Than does me good. I will arise and go.

Extracts from a notice of Charles Babbage, by A. Quetelet, of Brussels, translated from the "Annuaire de l'Observatoire royal de Bruxelles" for 1873.

Babbage says, in his passage from the Life of a Philosopher, "From my earliest years I had a great desire to inquire into the causes of all things and events which astonish the childish mind. At a later period I commenced the still more important inquiry into those laws of thought and those aids which assist the human mind in passing from received knowledge to that other knowledge then unknown to our race." These few lines express sufficiently well the character of the distinguished *savant* whose career we shall endeavor rapidly to sketch. Notwithstanding his own ardent desire to inquire into everything which could interest himself, our author never seems to have dreamed of informing others as to his exact age. According to his friends, he was born in 1792, and was consequently about 80 at the time of his death.

He did not begin seriously the study of mathematics until after the age of 22, when he was with his friend Herschel at Trinity College, Cambridge. They soon after published a joint work on mathematics, which did much toward introducing the continental methods and notation of this science into England. Fourteen years after this, while Mr. Babbage was in Rome, he accidentally read in an English newspaper the following paragraph: "Yesterday the bells of St. Mary rang out a peal

to celebrate the election of Charles Babbage as Lucasian professor of mathematics at Cambridge;" or, in other words, his appointment to the chair formerly occupied by Newton.

It was in Paris, in 1826, at a dinner given by Bouvard, the astronomer, that I had an opportunity to become acquainted with Babbage. There were at the same time present Poisson and several other of the scientists who then made Paris illustrious, with all of whom he was a center of interest. He, with truly fraternal kindness, offered me his assistance in procuring from the English mechanicians, among whom was the celebrated Troughton, the instruments for the Belgian observatory. He also proposed my co-operation in a work which he had projected which was to contain a register of everything capable of being measured, such as the specific gravity of bodies; the linear expansion of metals; their weight; the size of animals; the quantity of air they breathe; the nourishment they need, &c. "The extent of this work," I said, "is too vast to be carried out unless by the co-operation of many minds. The outline of what may be necessary for man alone is so great that with the help of many friends I could not hope to complete more than a skeleton of the whole." The reply was that time is an element of solution which overcomes the greatest difficulties of investigation; and if our efforts are properly directed our descendents will finish what we have properly begun.

Nothwithstanding his immense labor connected with the calculating-machine, Babbage, in April, 1835, turned his attention to assist his friend Herschel, then at the Cape of Good Hope, in carrying out over the whole world, on certain days, a system of meteorological observations. These days, which were called term-days, were the 21st of December, 21st of March, 21st of June, and 21st of September. At these times continued observations were to be made at every hour, commencing at noon on the days above mentioned and terminating the next day at the same hour. These observations, in the introduction of which Mr. Babbage took an active part, were continued in Europe, America, India, and Africa, and led finally to the establishment of the various systems of simultaneous weather-reports of the present day.

While I was in London, in 1851, at the great exhibition of industrial products, Babbage made me acquainted with Lord Lovelace, a gentleman of great ability and high reputation, who had married the cherished daughter of Lord Byron. This charming lady, remarkable for her beauty and personal accomplishments, and noted for her intellectual powers, had published a translation of an Italian account of the calculating-machine. She received me very graciously, and urged Mr. Babbage and myself to visit her frequently for conversation on literary and scientific subjects, with which she was familiar. She was especially interested in the calculus of probabilities, and so far did we carry our discussions on this point that it was agreed that we should

compose and publish a joint work on this subject. Unfortunately, the plan was prevented from being carried out by the premature death of this interesting lady.

I owe it to the friendship which long united me with Mr. Babbage to having seen in London, on several occasions and in the greatest detail, all the parts of the calculating-machine, and to having been able to form for myself a just conception of a labor of which I had often heard but of which very few people knew the particulars. The machine is certainly very complicated, and extreme attention is needed to follow the action of its different parts; hence, I shall not attempt to give a description of it, which would unquestionably fill quite a considerable volume if we paid respect to the ideas of the inventor, to the extreme perfection of the mechanical workmanship, and to all the mathematical calculations which the machine can perform.

Researches into statistics also claimed the attention of Babbage, and he was personally instrumental in adding to the committees of the British Association one on this subject. The attention of the committee on statistics was first turned to the need of exact documents in regard to population, a want much felt in England, especially as to everything relative to births, deaths, &c. Meetings were afterward held in London of persons interested in the subject of statistics, in which Mr. Babbage took an active part, and to which I was admitted. They examined, among other questions, that of the labor imposed upon children in manufacturies. The following questions were propounded to me in regard to Belgium, which I transmitted to the minister of the interior, who promised to have collected the necessary data for a satisfactory reply. The honorable *savants* asked—

"The number of births produced by each marriage during its entire length;

"The proportional number of children who reach the period of marriage;

"The number of children living by each marriage;

"The salaries paid in manufacturies and agriculture in different provinces, especially the price of an average day's labor in agriculture;

"The quantity of wheat which such a day's pay can procure in ordinary times;

"The mean price of different kinds of grain;

"The habitual food of the day-laborer;

"The proportional number of sterile marriages;

"The proportional number of marriages having five or six children living."

As an instance of our friend's singular disposition to enter upon investigations of the most out-of-the-way character, I may mention that for a time he lost sight of the profound speculations of political economy, and busied himself with the question as to how many times any letter

in different languages doubles itself in 10,000 words. The following table gives the result which he obtained:

Number of times different letters are doubled in ten thousand words.

Letters.	English.	French.	Italian.	German.	Latin.
A				1.5	
B			10.8		
C	9.4	7.2	23.7		8.2
D	1.9		1.1		4.4
E	18.9	7.2		19.4	
F	14.6	8.1	12.0	8.2	9.4
G	1.5		20.4		1.4
H					
I				0.4	8.9
J				0.8	
K				38.7	
L	16.1	55.5	70.6	21.2	36.5
M	6.4	25.7	12.0	19.7	5.9
N	8.3	17.7	20.4	0.4	4.4
O	12.7			0.4	
P	12.4	5.7	12.0		4.4
Q					11.2
R	12.7	32.2	10.8	7.8	41.7
S	13.9	44.2	53.7	53.5	5.9
T	13.1	12.0	64.5	9.3	5.2
U				1.9	
V			2.2		
W					
X					
Y					
Z			7.6		
Total	141.8	215.5	230.8	166.5	147.7

[In regard to the question of what use is this, we would remark that this question is never asked by the student of nature; since every item of knowledge is connected in some way with all other knowledge. Nothing can be said to be useless which tends to exhibit new relations, and indeed it is impossible to say *a priori* that a given fact may not find an application even in practice, however remote it may seem from anything of this kind. The results given in the foregoing investigation may be of importance in determining the casting of double types. The number of occurrences of a given letter in 10,000 words of any language determines the number of types of that letter in a font.—J. H.]

Our physicist always took care, in traveling, to carry with him those instruments which would enable him to carry on some investigations. He was essentially a man of experiment. He held that the eye and the ear were great aids to the judgment, and a demonstration never seemed to him complete until he knew how to render it evident to the sense and the reason. Toward the end of his life his vivacity was considerably moderated, and the mortification which he felt on account of not being able to complete his calculating-machine, and the loss of friends, cast a shadow over his latter days.

[I had myself the pleasure to make the acquaintance of Mr. Babbage in 1837, while he was in the zenith of his mental power, and to witness the operation of his first calculating-machine. I again visited him in 1870, after an interval of just one-third of a century. I found him in the

same house, still interested in the calculating-machine, with apparently but little diminution of mental activity. He informed me that he felt himself gradually declining; that he endeavored to note the change in himself; that he found it difficult to enter upon new subjects of thought, but that he could reason and mentally act on materials already in his mind in the way of new computations and new deductions. He regretted the loss of memory, since with it was the loss of personal identity.—J. H.]

[Extract from writings of Charles Babbage.]

OF OBSERVATIONS.

There are several reflections connected with the art of making observations and experiments, which may be conveniently arranged in this chapter.

Of Minute Precision.

No person will deny that the highest degree of attainable accuracy is an object to be desired, and it is generally found that the last advances toward precision require a greater devotion of time, labor, and expense than those which precede them. The first steps in the path of discovery and the first approximate measures are those which add most to the existing knowledge of mankind.

The extreme accuracy required in some of our modern inquiries has, in some respects, had an unfortunate influence by favoring the opinion that no experiments are valuable unless the measures are most minute and the accordance among them most perfect. It may, perhaps, be of some use to show that even with large instruments and most practiced observers this is but rarely the case. The following extract is taken from a representation made by the present astronomer-royal to the council of the Royal Society, on the advantages to be derived from the employment of two mural circles:

"That by observing, with two instruments, the same objects at the same time, and in the same manner, we should be able to estimate how much of that *occasional discordance from the mean, which attends even the most careful observations*, ought to be attributed to irregularity of refraction, and how much to the *imperfections of instruments*."

In confirmation of this may be adduced the opinion of the late M. Delambre, which is the more important, from the statement it contains relative to the necessity of publishing *all* the observations which have been made:

"Mais quelque soit le parti que l'on préfère, il me semble qu'on doit tout publier. Ces irregularités mêmes sont des faits qu'il importe de connoitre. *Les soins les plus attentifs n'en sauroient préserver les observateurs les plus exercés*, et celui qui ne produiroit que des angles toujours parfaitement d'accord auroit été singulièrement bien servi par les circonstances ou ne seroit pas bien sincère."—*Base de Système métrique, discours préliminaire*, p. 158.

This desire for extreme accuracy has called away the attention of experimenters from points of far greater importance, and it seems to have been too much overlooked in the present day that genius marks its track, not by the observation of quantities inappreciable to any but the acutest senses, but by placing Nature in such circumstances that she is forced to record her minutest variations on so magnified a scale that an observer, possessing ordinary faculties, shall find them legibly written. He who can see portions of matter beyond the ken of the rest of his species confers an obligation on them by recording what he sees; but their knowledge depends both on his testimony and on his judgment. He who contrives a method of rendering such atoms visible to ordinary observers communicates to mankind an instrument of discovery, and stamps his own observations with a character alike independent of testimony or of judgment.

On the Art of Observing.

The remarks in this section are not proposed for the assistance of those who are already observers, but are intended to show to persons not familiar with the subject that, in observations demanding no unrivaled accuracy, the principles of common sense may be safely trusted, and that any gentleman of liberal education may, by perseverance and attention, ascertain the limits within which he may trust both his instrument and himself.

If the instrument is a divided one, the first thing is to learn to read the verniers. If the divisions are so fine that the coincidence is frequently doubtful, the best plan will be for the learner to get some acquaintance who is skilled in the use of instruments, and, having set the instrument at hazard, to write down the readings of the verniers, and then request his friend to do the same. Whenever there is any difference, he should carefully examine the doubtful one, and ask his friend to point out the minute peculiarities on which he founds his decision. This should be repeated frequently, and, after some practice, he should note how many times in a hundred his reading differs from his friend's, and also how many divisions they usually differ.

The next point is, to ascertain the precision with which the learner can bisect an object with the wires of the telescope. This can be done without assistance. It is not necessary even to adjust the instrument, but merely to point it at a distant object. When it bisects any remarkable point, read off the verniers, and write down the result; then displace the telescope a little and adjust it again. A series of such observations will show the confidence which is due to the observer's eye in bisecting an object, and also in reading the verniers; and as the first direction gave him some measure of the latter, he may, in a great measure, appreciate his skill in the former. He should also, when he finds a deviation in the reading, return to the telescope and satisfy himself if he has made the bisection as complete as he can. In general, the student

should practice each adjustment separately, and write down the results wherever he can measure its deviations.

Having thus practiced the adjustments, the next step is to make an observation. But in order to try both himself and the instrument, let him take the altitude of some fixed object, a terrestrial one, and having registered the result, let him derange the adjustment, and repeat the process fifty or a hundred times. This will not merely afford him excellent practice, but enable him to judge of his own skill.

The first step in the use of every instrument is to find the limits in which its employer can measure the *same object under the same circumstances*, and, after that, of *different objects under different circumstances.*

The principles are applicable to almost all instruments. If a person is desirous of ascertaining heights by a mountain-barometer, let him begin by adjusting the instrument in his own study, and, having made the upper contact, let him write down the reading of the vernier, and then let him derange the *upper* adjustment *only*, re-adjust, and repeat the reading. When he is satisfied about the limits within which he can make that adjustment, let him do the same repeatedly with the lower, but let him not, until he knows his own errors in reading and adjusting, pronounce upon those of the instrument. In the case of a barometer, he must also be assured that the temperature of the mercury does not change during the interval.

A friend once brought me a beautifully-constructed piece of mechanism for marking minute portions of time; the three hundredth part of a second was indicated by it. It was a kind of watch, with a pin for stopping one of the hands. I proposed that we should each endeavor to stop it twenty times in succession at the same point. We were both equally unpracticed, and our first endeavors showed that we could not be confident of the twentieth part of a second. In fact, both the time occupied in causing the extremities of the fingers to obey the volition, as well as the time employed in compressing the flesh before the fingers acted on the stop, appeared to influence the accuracy of our observations. From some few experiments I made I thought I perceived that the rapidity of the transmission of the effects of the will depended on the state of fatigue or health of the body. If any one were to make experiments on this subject, it might be interesting to compare the rapidity of the transmission of volition in different persons with the time occupied in obliterating an impression made on one of the senses of the same persons. For example, by having a mechanism to make a piece of ignited charcoal revolve with different degrees of velocity, some persons will perceive a continuous circle of light before others, whose retina does not retain so long impressions that are made upon it.

On the Frauds of Observers.

Scientific inquiries are more exposed than most others to the inroads of pretenders; and I feel that I shall deserve the thanks of all who

really value truth, by stating some of the methods of deceiving practiced by unworthy claimants for its honors, while the mere circumstance of their arts being known may deter future offenders.

There are several species of impositions that have been practiced in science; which are but little known, except to the initiated, and which it may, perhaps, be possible to render quite intelligible to ordinary understandings. These may be classed under the heads of hoaxing, forging, trimming, and cooking.

Of Hoaxing.—This, perhaps, will be better explained by an example. In the year 1788, M. Gioeni, a knight of Malta, published at Naples an account of a new family of *Testacea*, of which he described with great minuteness one species, the specific name of which has been taken from its *habitat*, and the generic he took from his own family, calling it *Gioenia sicula.* It consisted of two round triangular valves, united by the body of the animal to a smaller valve in front. He gave figures of the animal, and of its parts; described its structure, its mode of advancing along the sand, the figure of the track it left, and estimated the velocity of its course at about two-thirds of an inch per minute. He then described the structure of the shell, which he treated with nitric acid and found it approached nearer to the nature of bone than any other shell.

The editors of the *Encyclopédie méthodique* have copied this description and have given figures of the *Gioenia sicula.* The fact, however, is, that no such animal exists, but that the knight of Malta, finding on the Sicilian shores the three internal bones of one of the species of *Bulla*, of which some are found on the southwestern coast of England,* described and figured these bones most accurately, and drew the whole of the rest of the description from the stores of his own imagination.

Such frauds are far from justifiable; the only excuse which has been made for them is, when they have been practiced on scientific academies which had reached the period of dotage.

It should, however, be remembered that the productions of nature are so various that mere strangeness† is very far from sufficient to render doubtful the existence of any creature for which there is evidence; and that, unless the memoir itself involves principles so contradictory‡ as to outweigh the evidence of a single witness, it can only be regarded as a deception without the accompaniment of wit.

Forging differs from hoaxing, inasmuch as in the latter the deceit is intended to last for a time, and then be discovered to the ridicule of

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**Bulla lignaria.*

†The number of vertebræ in the neck of the *Plesiosaurus* is a strange but ascertained fact.

‡ The kind of contradiction which is here alluded to is that which arises from *well-ascertained* final causes; for instance, the ruminating stomach of the hoofed animals is in no case combined with the claw-shaped form of the extremities, frequent in many of the carnivorous animals, and necessary to some of them for the purpose of seizing their prey.

those who have credited it; whereas the forger is one who, wishing to acquire a reputation for science, records observations which he has never made. This is sometimes accomplished in astronomical observations by calculating the time and circumstances of the phenomenon from tables. The observations of the second comet of 1784, which was only seen by the Chevalier d'Angos, were long suspected to be a forgery, and were at length proved to be so by the calculations and reasoning of Encke. The pretended observations did not accord among each other in giving any possible orbit. But M. Encke detected an orbit, belonging to some of the observations, from which he found that all the rest might be almost precisely deduced, provided a mistake of a unit in the index of the logarithm of the radius vector were supposed to have been made in all the rest of the calculations. (*Zach. Corr. Astron.*, tom. iv, p. 456.)

Fortunately, instances of the occurrence of forging are rare.

Trimming consists in clipping off little bits here and there from those observations which differ most in excess from the mean, and in sticking them on to those which are too small; a species of "equitable adjustment," as a radical would term it, which cannot be admitted in science.

This fraud is not, perhaps, so injurious (except to the character of the trimmer) as cooking, which the next paragraph will teach. The reason of this is, that the *average* given by the observations of the trimmer is the same, whether they are trimmed or untrimmed. His object is to gain a reputation for extreme accuracy in making observations; but from respect for truth, or from a prudent foresight, he does not distort the position of the fact he gets from nature, and it is usually difficult to detect him. He has more sense or less adventure than the cook.

Of Cooking.—This is an art of various forms, the object of which is to give to ordinary observations the appearance and character of those of the highest degree of accuracy.

One of its numerous processes is to make multitudes of observations, and out of these to select those only which agree or very nearly agree. If a hundred observations are made, the cook must be very unlucky if he cannot pick out fifteen or twenty which will do for serving up.

Another approved receipt, when the observations to be used will not come within the limit of accuracy which it has been resolved they shall possess, is to calculate them by two different formulas. The difference in the constants employed in those formulas has sometimes a most happy effect in promoting unanimity among discordant measures. If still greater accuracy is required, three or more formulas can be used.

It must be admitted that this receipt is in some instances most hazardous; but in the cases where the positions of stars, as given in different catalogues, occur, or different tables of specific gravities, specific heats, &c., it may safely be employed. As no catalogue contains all stars, the computer must have recourse to several; and if he is obliged to use his judgment in the selection, it would be cruel to deny

him any little advantage which might result from it. It may, however, be necessary to guard against one mistake into which persons might fall.

If an observer calculate particular stars from a catalogue which makes them accord precisely with the rest of his results, whereas had they been computed from other catalogues the difference would have been considerable, it is very unfair to accuse him of *cooking;* for those catalogues may have been notoriously inaccurate, or they may have been superseded by others more recent, or made with better instruments; or the observer may have been totally ignorant of their existence.

It sometimes happens that constant quantities in formulas given by the highest authorities, although they differ among themselves, yet they will not suit the materials. This is precisely the point in which the skill of the artist is shown; and an accomplished cook will carry himself triumphantly through it, provided, happily, some mean value of such constants will fit his observations. He will discuss the relative merits of formulas he has just knowledge enough to use; and, with admirable candor, assigning their proper share of applause to Bessel, to Gauss, and to Laplace, he will take *that* mean value of the constant used by three such philosophers which will make his own observations accord to a miracle.

There are some few reflections I would venture to suggest to those who cook, although they may not receive the attention which, in my opinion, they deserve, from not coming from the pen of an adept.

In the first place, it must require much time to try different formulas. In the next place, it may happen that, in the progress of human knowledge, more correct formulas may be discovered, and constants may be determined with far greater precision. Or it may be found that some physical circumstance influences the results, (although unsuspected at the time,) the measure of which circumstance may perhaps be recovered from other contemporary registers of facts.* Or, if the selection of observations has been made with the view of its agreeing precisely with the latest determination, there is some little danger that the average of the whole may differ from that of the chosen ones, owing to some law of nature dependent on the interval between the two sets, which law some future philosopher may discover; and thus the very best observations may have been thrown aside.

In all these, and in numerous other cases, it would most probably happen that the cook would procure a temporary reputation for unrivaled accuracy at the expense of his permanent fame. It might also have the effect of rendering even all his crude observations of no value; for that part of the scientific world whose opinion is of most weight is generally so unreasonable as to neglect altogether the observations of those in

* Imagine, by way of example, the state of the barometer or thermometer.

whom they have, on any occasion, discovered traces of the artist. In fact, the character of an observer, as of a woman, if doubted, is destroyed.

The manner in which facts apparently lost are restored to light, even after considerable intervals of time, is sometimes very unexpected, and a few examples may not be without their use. The thermometers employed by the philosophers who composed the Accademia del Cimento have been lost; and as they did not use the two fixed points of freezing and boiling water, the results of a great mass of observations have remained useless from our ignorance of the value of a degree on their instruments. M. Libri, of Florence, proposed to regain this knowledge by comparing their registers of the temperature of the human body and of that of some warm springs in Tuscany which have preserved their heat uniform during a century, as well as of other things similarly circumstanced.

Another illustration was pointed out to me by M. Gazzeri, the professor of chemistry at Florence. A few years ago an important suit in one of the legal courts of Tuscany depended on ascertaining whether a certain word had been erased by some chemical process from a deed then before the court. The party who insisted that an erasure had been made availed themselves of the knowledge of M. Gazzeri, who, concluding that those who committed the fraud would be satisfied by the disappearance of the coloring matter of the ink, suspected (either from some colorless matter remaining in the letters, or perhaps from the agency of the solvent having weakened the fabric of the paper itself beneath the supposed letters) that the effect of the slow application of heat would be to render some difference of texture or of applied substance evident by some variety in the shade of color which heat in such circumstances might be expected to produce. Permission having been given to try the experiment, on the application of heat the important word re-appeared, to the great satisfaction of the court.

[One of the most noted deceptions of this kind was that called the moon hoax, published in New York about thirty years ago, which purported to be a series of discoveries made in the moon by Sir John Herschel during his residence at the Cape of Good Hope. These discoveries were said to be the result of a great improvement in the telescope. It is well known that, with a given-sized object-glass, the power of this instrument is limited by the degree to which the image in the focus of the glass can be magnified; the light remaining the same, the more the size of the image is increased the darker it becomes. The alleged improvement consisted in the illumination of this image by artificial light. By the application of this idea, the telescope employed by the astronomer at the Cape of Good Hope admitted of an eye-glass of such magnifying power that moving objects on the surface of the moon were observable, and men and animals of remarkable forms were actually discovered.

It is astonishing the effect which the annunciation of these discoveries produced. Instead of detecting at once the scientific absurdity of illu-

minating a shadow in order that it might be more highly magnified, many persons, even professors in colleges, gave the announcement credence, and thus added to the popularity of the hoax. This fraud owed its success, in a great measure, to a want, at the time, of precise scientific knowledge in this country, and after the absurdity was pointed out the invention was cried up as a most extraordinary production, since those who had been hoaxed by it attributed their credulity to the ingenuity of the deception rather than to their own want of knowledge.

The success of this hoax has had an exceedingly bad influence on the character of our country for veracity. It was followed immediately after, and has been even down to the present time, by a series of contemptible imitations; and, indeed, to such an extent was this imitation carried on a few years ago, that scarcely any announcement of phenomena of unusual occurrence could be accepted as truth. Among these imitations within a few years, the most successful, and one which evinced considerable reading as well as ingenuity, was that of the pretended discovery of a series of Runic inscriptions on the face of a rock in the Potomac River near Washington. This was the invention of a young student of law in this city, and excited quite a sensation among the archæologists of this and other countries. It was copied in various ethnological journals as a truth, and was hailed by the Scandinavians as a new evidence of the early explorations of the Northmen in the United States.

Such inventions must be classed with those practical jokes which have been happily termed "gymnastic wit," of which a notable example was given in England, where a "society" was founded for "insulting women and frightening children." The chronicler naively remarks that the members were never discovered, and, what is just as remarkable, the wit was equally a mystery. "Truth," says Dr. Johnson, "is a matter of too much importance to be tampered with, even in trifles."—J. H.]

On the Permanent Impression of our Words and Actions on the Globe we inhabit.

The principle of the equality of action and reaction, when traced through all its consequences, opens views which will appear to many persons most unexpected. The pulsations of the air, once set in motion by the human voice, cease not to exist with the sounds to which they gave rise. Strong and audible as they may be in the immediate neighborhood of the speaker, and at the immediate moment of utterance, their quickly-attenuated force soon becomes inaudible to the human ears. The motions they have impressed on the particles of one portion of our atmosphere are communicated to constantly-increasing numbers, but the total quantity of motion measured in the same direction receives no addition. Each atom loses as much as it gives, and regains again from other atoms a portion of those motions which they in turn give up.

The waves of air thus raised perambulate the earth and the ocean's surface, and in less than twenty hours every atom of its atmosphere takes up the altered movement due to that infinitesimal portion of the primitive motion which has been conveyed to it through countless channels, and which must continue to influence its path throughout its future existence.*

But these aerial pulses, unseen by the keenest eye, unheard by the acutest ear, unperceived by human senses, are yet demonstrated to exist by human reason; and, in some few and limited instances, by calling to our aid the most refined and comprehensive instrument of human thought, their courses are traced and their intensities are measured. If man enjoyed a larger command over mathematical analysis, his knowledge of these motions would be more extensive; but a being possessed of unbounded knowledge of that science could trace every the minutest consequence of that primary impulse. Such a being, however far exalted above our race, would still be immeasurably below even our conception of infinite intelligence.

But supposing the original conditions of each atom of the earth's atmosphere, as well as all the extraneous causes acting on it, to be given, and supposing also the interference of no new causes, such a being would be able clearly to trace its future but inevitable path, and he would distinctly foresee and might absolutely predict for any, even the remotest period of time,† the circumstances and future history of every particle of that atmosphere.

Let us imagine a being, invested with such knowledge, to examine at a distant epoch the coincidence of the facts with those which his profound analysis had enabled him to predict. If any the slightest deviation existed, he would immediately read in its existence the action of a new cause; and, through the aid of the same analysis, tracing this discordance back to its source, he would become aware of the time of its commencement and the point of space at which it originated.

Thus considered, what a strange chaos is this wide atmosphere we breathe! Every atom, impressed with good and with ill, retains at once the motions which philosophers and sages have imparted to it, mixed and combined in ten thousand ways with all that is worthless and base. The air itself is one vast library, on whose pages are forever written all that man has ever said or woman whispered. There, in their mutable but unerring characters, mixed with the earliest as well as with the latest sighs of mortality, stand forever recorded, vows unredeemed, promises unfulfilled, perpetuating in the united movements of each particle, the testimony of man's changeful will.

But if the air we breathe is the never-failing historian of the sentiments

* "La courbe décrite par une simple molécule d'air ou vapeurs est réglée d'une manière aussi certain que les orbites planétaires; il n'y a de différence entre elles que celle qu'y met notre ignorance."—*La Place, Théorie Analytique des probabilités, introduction*, p. iv.

† See note C in the Appendix.

we have uttered, earth, air and ocean are the eternal witnesses of the acts we have done. The same principle of the equality of action and re-action applies to them; whatever movement is communicated to any of their particles is transmitted to all around it, the share of each being diminished by their number, and depending jointly on the number and position of those acted upon by the original sources of disturbance. The waves of air, although in many instances perceptible to the organs of hearing, are only rendered visible to the eye by peculiar contrivances; but those of water offer to the sense of sight the most beautiful illustration of transmitted motion. Every one who has thrown a pebble into the still waters of a sheltered pool has seen the circles it has raised, gradually expanding in size, and as uniformly diminishing in distinctness. He may have observed the reflection of those waves from the edges of the pool. He may have noticed also the perfect distinctness with which two, three, or more series of waves each pursues its own unimpeded course, when diverging from two, three, or more centers of disturbance. He may have seen, in such cases, the particles of water where the waves intersect each other partake of the movements due to each series.

No motion impressed by natural causes or by human agency is ever obliterated. The ripple on the ocean's surface, caused by a gentle breeze, or the still water which marks the more immediate track of a ponderous vessel gliding with scarcely expanded sails over its bosom, are equally indelible. The momentary waves raised by the passing breeze, apparently born but to die on the spot which saw their birth, leave behind them an endless progeny, which, reviving with diminished energy in other seas, resisting a thousand shores, reflected from each, and perhaps again partially concentrated, will pursue their ceaseless course till ocean be itself annihilated.

The track of every canoe, of every vessel which has yet disturbed the surface of the ocean, whether impelled by manual force or elemental power, remains forever registered in the future movement of all succeeding particles which may occupy its place. The furrow which it left is, indeed, instantly filled up by the closing waters; but they draw after them other and larger portions of the surrounding element, and these again once moved communicate motion to others in endless succession.

The solid substance of the globe itself, whether we regard the minutest movement of the soft clay which receives its impression from the foot of animals, or the concussion arising from the fall of mountains rent by earthquakes, equally communicates and retains, through all its countless atoms, their apportioned shares of the motions so impressed.

While the atmosphere we breathe is the ever-living witness of the sentiments we have uttered, the waters, and the more solid materials of the globe, bear equally enduring testimony of the acts we have committed.

If the Almighty stamped on the brow of the earliest murderer the indelible and visible mark of his guilt, he has also established laws by which every succeeding criminal is not less irrevocably chained to the testimony of his crime; for every atom of his mortal frame, through whatever changes its several particles may migrate, will still retain, adhering to it through every combination, some movement derived from that very muscular effort by which the crime itself was perpetrated.

The soul of the negro whose fettered body, surviving the living charnel-house of his infected prison, was thrown into the sea to lighten the ship, that his Christian captor might escape the limited justice at length assigned by civilized man to crimes whose profit had long gilded their atrocity, will need, at the last great day of human account, no living witness of his earthly agony. When man and all his race shall have disappeared from the face of our planet, ask every particle of air still floating over the unpeopled earth, and it will record the cruel mandate of the tyrant.

LOUIS AGASSIZ.

A DISCOURSE DELIVERED BY REV. RUFUS P. STEBBINS, D. D., OF ITHACA, NEW YORK.

Agassiz is dead! Science weeps, and Religion mourns. Nature has lost a friend, and asks, "Who will now read the inscribed leaves of my rocky tablets with such loving enthusiasm? Who will now study and describe all living things with such sympathetic admiration?"

Agassiz is dead! No more will he walk the gray cliffs of Nahant, lifted into communion with highest themes by the voice of the ocean's anthem! No more will he traverse the coral reefs of Florida to learn how promontories and islands are built by the tiniest and frailest of living things! No longer will he visit the high Alps, and measure the velocity and force of its great rivers of ice, to teach us how the rocks have been carved on the mountain-tops, and scattered over the valleys! No longer will he dredge the depths of the ocean to astonish the world with the living creatures which have their home a thousand fathoms below the storms! No longer will he examine with kindling enthusiasm the germinating egg under his microscope, and thrill the scientific world with delight as he announces some new phenomenon, illustrating some new method of the divine order! No more will he be seen in his museum, the pride of his heart, the joy of his life! Never again will he visit Penikese, where, with such ardor he last summer opened his new school to study living nature and not merely the printed page, and where he, the man of science, paid such a memorable tribute to religion!* No more shall we meet that regal form, look into that beaming face, grasp that warm hand, hear those wise and cheering words! His personal work here is done. But he has inspired thousands to press after the truth; he has founded an institution which will live after him in ever-increasing efficiency and usefulness. His praise will be spoken by tongues in all languages, in the most ancient and renowned universities of the world. Thousands of hearts will mourn his absence in halls of science before whose assemblies of the foremost scholars of two continents he laid the golden treasures of his researches with the simplicity and joy of a child. How many of his pupils, whose names are even now high authority, will forget the stern requirements of the teacher in their admiration of the man, and their gratitude for the enthusiasm with which he inspired them, the very accuracy of observation to which he compelled them! Thousands of intelligent citizens will look in vain for those reported lectures, so transparent in style, so clear in description, which have been a joy and a revelation to them for the last quarter of a century.

* See "Prayer of Agassiz," by Whittier.

Agassiz is dead! Well may the flags of his adopted city fall to half-mast! Well may the orator pause in the torrent of his argument and drop a tribute to his memory! Well may the bells of our universities toll at the hour of his funeral, for he was not of one university but of all! Well may the academies of science on both continents record his worth in memorial resolutions, for he was of both continents; nay, of the world! In the midst of this wide appreciation of the wonderful labors and discoveries of Agassiz, this universal showering of tributes upon his grave, by the learned, the world-renowned; I tremblingly bring my single leaf to be lost among the pyramids of flowers, of no importance to the grateful pile, but of great importance to the promptings, the demands of my own heart.

Louis John Rudolph Agassiz was born May 28, 1807, in the parish of Mottier, near Lake Neufchatel, in Switzerland.

And Nature, the dear old nurse, took
  The child upon her knee,
Saying, "Here is a story-book
  Thy Father has written for thee."
"Come, wander with me," she said,
  "Into regions yet untrod,
And read what is still unread
  In the manuscripts of God."

He was of Huguenot descent, and his ancestors were driven from France by the revocation of the edict of Nantes. For six generations his lineal ancestors had been clergymen. His mother was a woman of uncommon intelligence, and had special oversight of his early education, and just pride in his mature fame; and in after life, Agassiz illustrated the depth of his gratitude and filial love by laying aside his studies, from which nothing else could call him, to make the voyage to Europe and the journey to Switzerland, that he might once more receive his mother's blessing and give her his own.

At the age of eleven years young Agassiz was sent to school at Bienne for four years, where he studied the ancient and modern languages, and amused himself by observing the habits of fishes and collecting insects. During his vacations, spent at his father's new home under the shadow of the Jura, by the influences of a young clergyman named Fivaz, he was first inspired with a love of the natural sciences, and he became interested in botany. When fifteen years of age, Louis entered college at Lausanne, where he remained two years, and having determined to study medicine he went to Zurich when he was seventeen years old, where he remained two years. Wishing to avail himself of the best educators, he went to Heidelberg when nineteen, devoting himself to the study of anatomy and physiology and zoology and botany under such professors as Tiedemann, Leuckart, and Bischoff. But as the university at Munich had then been re-organized, with the most eminent scientists on the continent in its faculty, young Agassiz was attracted

thither in his twentieth year; for his motto thus early in life seems to have been, "Of instruction, the best; of investigation, perfection." There were Oken and Martius and Schelling and Döllinger, each of whom was an original investigator and discoverer, founder even of some branches of science. He was received to the intimacy of these eminent men—a vast advantage, when there is manhood behind acquisitions, and sense behind genius; otherwise, the sorest misfortune that can befall a student. There young Agassiz reveled in all the luxuries of original investigations for four years. His fellow-students were delighted with the brilliancy of his discussions, and he was the inspiring genius of a select society of young men who were engaged in scientific studies, which embodied so much talent and made such discoveries that it was called the Little Academy, and attracted the presence and participation of the professors. During these four years he published a few special papers. But he at once placed himself in the foremost rank of naturalists by his discussion and classification of the fishes of Brazil, to which work he was assigned by his teacher Martius. It was published in Latin in folio. This was his first work, his first contribution to natural science.

Agassiz was now twenty-four years of age. His thirst for the study of natural science had become so strong that he was diverted from the profession of medicine which his parents wished him to adopt, and became an interpreter of nature. He lost thereby the paternal allowance, but gained mental independence. He took his doctorate of philosophy at Erlangen with distinction, after an unusually severe examination. He obtained his degree of doctor of medicine in the same year at Munich, and maintained in his thesis the superiority of woman to man.

Agassiz was now a graduate with high honors, and with the world before him as an inheritance—the world full of richest fields to be explored. For twenty-two years, till his coming to America in 1846, he gave himself with most unbounded enthusiasm and herculean labor to original investigations; spending weeks over his microscope in observing the changes in the processes of the growth of animal life from the germ to the mature form; following the courses of rivers and visiting the different basins of Europe to determine the distribution of its fishes; traversing the lake-shores and mountains of Switzerland to learn the causes of the erosion of the rocks and the transportation of the bowlders; visiting England and Scotland to compare the insular with the continental phenomena; pitching his tent, season after season, upon the Alpine glaciers that he might study accurately their movements and force; making the acquaintance of the princes of science and taken joyfully into their intimacy—Humboldt, Cuvier, Baer, Owen, Murchison; and, calling around him the most accomplished artists, in his own study, under his own eye, he caused to be drawn from nature and printed an outline of the results of all these travels, observations, and acquisitions. First came his great work on the "Natural History of the Fresh-Water Fishes of Europe,"

full of original suggestions, and proposing some theories of local creations, which startled the scientific world, and whose discussion has hardly yet subsided. Then came his greater work on "Fossil Fishes." He devoted seven years to the investigation of the subject before he commenced publishing. He visited all the great collections in Europe and England, accompanied by a skillful artist to make his drawings. More than eighty museums, public and private, were visited by him, and from which he was permitted to retain some of the most rare and precious specimens for many years that he might make his work as perfect as possible by repeated and rigid comparisons. The last sheets of this work came before the public in 1844, having been in the press ten years, and containing the results of seventeen years' study, *such study* as few but Agassiz understood and accomplished. This work was in five large volumes, with a folio atlas, containing four hundred plates. One thousand species are figured in their natural size with the colors of their beds, and seven hundred species more are partially represented and described. New types of fishes were discovered, and a new classification was rendered necessary by the publication of this work. And hardly less important was its influence upon geology than upon ichthyology. The relative ages of different formations were more accurately determined by these fossils. The relations of the other classes of vertebrates were also discovered, and some very important general conclusions were drawn from these seventeen years' study of paleontology and collateral investigations. The indications of purpose, of designed arrangement everywhere discovered, not only in the teeth of the fossil shark but also in the arm of a polyp, so impressed his mind that he affirmed the "existence of a superior intelligence to have been established by *rigid demonstration* and on a *truly scientific basis.*" "Have we not," he exclaims at the close of his work, after summing up its great facts, "have we not here proof of the existence of a mind as powerful as prolific? the acts of an intelligence as sublime as provident? the marks of goodness as infinite as wise? The most *palpable demonstration of the existence of a personal God, Author of all things, Ruler of the universe, and Dispenser of all good?* This, at least, is what I read in the works of creation." The great paleontologist was led from Nature up to Nature's God.

While Agassiz was preparing this great work for the press, a labor one would suppose equal to any student's strength, and sufficient to gratify any student's ambition, he made most elaborate original investigations, and published monographs, upon "Fossil and Living Radiates and Mollusks," accompanied with full descriptions of their habits and relations. During the same period, as if his strength was as inexhaustible as the fields of science which he cultivated, he published his "Zoological Nomenclature," (*Nomenclator Zoologicus,*) containing the names of all the genera in the animal kingdom, and the names of the students who first proposed them, and the time when they were given. And to this he added another and very important work, the "Library

of Zoology and Geology," (*Bibliotheca Zoologiæ et Geologiæ,*) in which he gave a list of the works of the authors named in the former publication, with such notices as they seemed to demand. It was published in England in four large octavo volumes.

But the work of these seventeen years is not yet all told. For nine years Agassiz spent his summer-vacations among the Alps. He published two very able works containing the result of his observations, and including the germs of his "Glacial Theory," which he afterward announced, and which is now one of the greatest objects of interest to the geologist. And still more: during fourteen of these seventeen years he was professor of natural history in the College of Neufchatel; and a most enthusiastic teacher he was. His fame became co-extensive with civilization. The scientific societies and learned academies of both the old world and the new hastened, in generous rivalship, to do themselves the honor of recognizing his unsurpassed merits as a student of nature. The prizes of successful investigations and new discoveries were received from kings and emperors. Learned degrees were conferred upon him by the great universities of the continent and of England. His name was a synonym for scientific genius, indomitable labor, and brilliant achievement. Having become familiar with the scenery and the flora and fauna, both fossil and living, which beautified and inhabited the old world, or were buried in its sepulchers, a new world was given him to conquer.

In 1846, at the age of thirty-nine years, he received from the King of Prussia, at the suggestion of Baron Alexander von Humboldt, a commission to visit the United States, and make explorations in behalf of science, and at the same time he received an invitation to come over and deliver a course of lectures before the Lowell Institute in the city of Boston.

At this time there were very few scholars in the United States who had given any special attention to the higher problems of zoology. Most of the studies in regard to it had been confined to the description and classification of new species, and there was not in all our colleges a single chair devoted to instruction in this branch of natural history. There was, however, an awakening attention to it; the study of the microscope had been introduced, and the use of this instrument was beginning to be applied to the verification of the discoveries which had been made in Europe. Agassiz came at this period of awakening, bringing with him a European reputation, miraculous stores of knowledge at perfect command, years of experience as teacher and out-door observer, with a most winning and commanding presence; fascinating as a lecturer, though pronouncing our language quite imperfectly; magnetic in his influence upon hearers, so that those who left his presence knew not which had most captivated them, the perfectness of his knowledge, the transparency of his descriptions, or the warmth of his heart.

His lectures were crowded. He took Boston, as it were, by storm.

The lecture of the evening was repeated the next afternoon, and still there was not room; still there were unsatisfied ears; still there were longing hearts. He met the little coteries of amateurs, and amazed them as he narrated the length and persistency of his observations of some of the changes and transformations of the lower forms of living creatures. One of the most eminent of the microscopists of the city stated to a club the results of three or four days' observations of some objects under his glass; and those obtained were so meager that he had laid all further inquiry aside. A discussion was started, and after an expression of opinion from different members respecting the *practicability* of obtaining any satisfactory results as to the subject under investigation, Agassiz, their guest, was called upon for his opinion. He amazed them all by saying that he had made an investigation of this subject, but instead of continuing it only three days, he had continued it for six weeks, night and day, at regular intervals, so that no change could take place without his notice, and the result was most satisfactory, confirming his conjectures respecting the class in the animal kingdom to which the objects should be referred. "Six weeks, *night and day*!" Our amateurs had not dreamed of such persistent labor. Nor did they dream of it in the future, but commenced to practice it in the present, and, under the influence of Agassiz, were transformed from mere amateurs to working zoologists.

Indeed, such was the effect of the sympathy and enthusiasm which he exerted that, thenceforward and to-day, you will find merchant-princes and bankers of Boston hastening, after business-hours, not to club-rooms, but to their homes, to seat themselves at the eye-glass of their expensive microscopes to continue their observations of the habits and transformations of the crowded population of a drop of sea-water or a spray of alga. The spirit of Agassiz took possession of their souls.

But I am running before my story. The brightness of its termination has attracted me from the less brilliancy of its commencement. But to trace with any minuteness the labors of Agassiz for the last twenty-six years of his life in this discourse would be impossible. It would be almost like writing the history of some branches of science.

His first course of lectures was fully reported in one of the Boston papers, together with the illustrations which he gave on the blackboard. He was at once called upon to lecture in the great cities of the country, and overwhelmed with invitations to meet with scientific societies and social assemblies. The latter he almost invariably declined; the former he as uniformly accepted.

His commission from the King of Prussia introduced him to our Government, and he was invited as a guest on board the vessels of the Coast Survey, and dredged the ocean along our coast, gathering new and abundant specimens for future examination.

The next year, 1847, the Lawrence Scientific School was founded at Cambridge in connection with Harvard University, and Agassiz was

appointed in this professor of geology and zoology. He now determined to make this country his home, and sent for a discharge from his commission given by the King of Prussia. It was granted him in the assurance "that wherever he took up his abode, his time would be employed to the best advantage of science."

At this time there was no collection of specimens of zoology in America which would compare for a moment with the museums of the Old World; and it now became with Agassiz an absorbing passion of his life to found one which should rival the richest that the ambition and wealth of emperors and empires had established. His enthusiasm sent collectors to the steaming bayous of the Gulf, the frozen coast of Labrador, and around the unexplored shores of the northern lakes. He inspired with one purpose young and old, on land and on sea. The Pacific as well as the Atlantic coast was his tributary. Every ship brought him some contribution. Every train paid tribute to his accumulating riches. Traveling from city to city, and charming as well as instructing by his lectures, he enlisted young and old in his great enterprise till it seemed as if the whole population of the country were his agents or assistants. Stored in barns, in warehouses, in cellars, and in attics, Cambridge was full of packages for the museum. The hour was fully come. He now turned his back more promptly and firmly against all temptations to abandon his great purpose. To an offer to give his knowledge and genius to the advantage of a great pecuniary undertaking which would have poured a fortune into his lap, he simply replied, "*I have no time to make money.*" When Napoleon, at the recommendation of the academy, invited him to the highest scientific position in France, and intimated, not obscurely, that as a citizen of France it was hardly right or honorable for him to give his transcendent talent and world-wide fame to a new and unscientific country, and not to add to the renown of the institutions of the land of his ancestors enriched by imperial bounties and honors, he replied in substance that he was not a citizen of France, and that his family and ancestors owed nothing to France but exile and poverty; that he prized more highly the spontaneous gratitude and gifts of a free people than the patronage of emperors and the formal regard of nobles.

His great work, "Contributions to the Natural History of the United States," had been commenced; the school which his wife had opened in his house for young ladies, to aid in supporting his family, was in full success and received daily lectures from him; he was overwhelmed, not only with correspondence on scientific subjects from all parts of the world, but with specimens, so that the neighborhood of his work-room often appeared like the storehouse of an importer. The college had already purchased his earlier collections to enable him to collect more. After *twelve* years of indefatigable labor, the mass of materials had become simply enormous; and there was no place to store them in security, much less any place where they could be either exhibited or studied. What could be done? The will of Francis C. Gray, of

Boston, was at this moment opened, and a bequest of $50,000 was found for the museum. This was the first ray of morning, showing that the day was coming from behind the mountains.

Agassiz seemed filled with a prophet's enthusiasm and assurance; his face shone brighter and brighter as the day advanced. *Seventy thousand dollars* were raised by subscription in Boston and its vicinity in a few months, and the next winter the great scientist, with the faith of a saint and the prospect of a martyr, went before the Massachusetts legislature of *farmers* and *mechanics* to ask for $100,000 to aid him in his work! Remember this was immediately after the universal bankruptcy of 1857. What a hopeless mission, to ask, under *such* circumstances and of *such* men, an appropriation of one hundred thousand dollars to promote purely scientific inquiries; to aid in gathering rocks and bones and fishes and shells and insects, and erecting a building in which to store them! But Agassiz's enthusiasm was so great that there was no room for doubt; he could not disbelieve; he would not hesitate. He met the committee of the legislature appointed to hear him explain his proposition. The hearing was in the hall of the house of representatives, and all the members of both bodies of the legislature, allured by his fame, crowded to hear him. Incarnate science stands in the presence of incarnate expediency, thrift, and palpable economy! What could he say? The great interpreter of nature made no appeal to love of gain. He could promise no golden treasures in return for their bounty. He did not tell them that he could make the crops more abundant, the soil more fertile, the fabrics more marketable. He said that he would have the wonderful works of nature, of God, better illustrated, more carefully studied. He would have Massachusetts—and here with consummate adroitness he touched the tenderest spot in the sensibilities of the old Bay State—*keep the lead* in the great educational movements of the century. He had determined to give his life to *that end* if *she would aid him!* "My great object," these are his very words, "is to have a museum founded here which will be equal to the great museums of the Old World. We have a *continent* before us for exploration, which has as yet been only *skimmed on the surface*. My earnest desire has always been, and is now, to put our universities on a footing with those of Europe or even ahead of them." Science was honored in the presentation of her representative. Neither party nor pelf soiled the whiteness of her robes. But when the question came before the house for consideration an attempt was made to throw ridicule on the proposition by designating the establishment where science was to be honored a "Palace for Bugs." But this attack was repelled; the appropriation asked for was granted, and Agassiz triumphant, with over two hundred thousand dollars at his command, broke ground for his "Museum of Comparative Zoology."

At this period I became personally acquainted with him. His hands, his heart, his head, were full. Fortunately he had matured his plan for

his building during previous years. He had introduced into it all the excellencies of the best museums of Europe, and added many which his own experience had suggested. It was to cover three sides of a square, and but half of one of the wings was to be undertaken at this time. He would build as he needed, but permanently and perfectly for all coming time. And when it was finished and filled with specimens, like the widow's cruse of oil, everything was still full; hundreds of precious packages still unopened; hundreds of capacious casks still untouched. For once the great heart of Agassiz faltered; his hands fell helplessly by his side; he stood still. The pause was but for a moment; the embarrassment was one of riches. He saw in vision the walls of the rest of the wing arise, and he now set himself to accomplish it. He went to the Amazon, sent out by a princely banker of Boston, who gave him a *carte blanche*, to draw on him for what means he required. With an enthusiasm which consumed his very life, regardless of exposure, shrinking from no labor, he navigated and forded rivers, penetrated thickets, and collected treasures for his future cabinets, which amazed himself and his enthusiastic and laborious companions, when they arrived at Cambridge.

The legislature again aided him. Congress remitted the tariff on the alcohol needed for the preservation of his stores. With lecturing, writing, collecting, arranging, his active brain grew dizzy, his broad shoulders bowed, his firm step trembled. He must close his books; he must leave his laboratory; he must not read; he must not think; he must take himself away from all inquiries, and rest. I met him in his exile at the White Mountains when he was convalescing. He greeted me with his usual cheerful heartiness, and thanked me with his usual cordiality when I expressed a confident expectation of seeing him soon in the museum at Cambridge. But he never regained his former health. The work at the museum, however, went on under his general supervision. The addition to the wing was completed, the shelves, the cases, the jars all filled, and still the masses of his collections were hardly perceptibly diminished.

He was again working too hard. Arrangements were made to allure him from his tasks in Cambridge by holding out to him greater attractions. He was invited by Professor Pierce to make a voyage in a Coast Survey vessel around Cape Horn to San Francisco; and her commander was instructed to give him such opportunities as he desired for dredging in deep water, and making inland excursions when possible. Accompanied by his wife and his intimate scientific friend, Rev. Dr. Hill, ex-president of Harvard University, and one or two others, he performed the voyage with his usual success in the line of new discoveries and abundant collections. Landing at San Francisco, he was welcomed with an ovation worthy of the head of a nation. Here his enthusiasm became epidemic, and a scientific spirit was awakened which has resulted in an endowment for its advancement of a million of dollars. He returned to Cambridge much improved in health by his voyage, and gave

himself again to the examination and arrangement of the great stores of his recent collection, with a devotion and enthusiasm which filled the hearts of his friends with fear lest he should again break down. But he could not refrain from living among his treasures, and directing the orderly and scientific study of everything. And so perfectly was it done, that in his last report he says, "The scientific officers of the museum have so efficiently carried on the work that the past year has proved beyond question that it is now so organized (vitalized as it were with the spirit of thought and connected with work) that my presence or absence is of little importance. It will keep on its course without any new or repeated stimulus beyond the necessary appropriations for its maintenance."

It would seem that there was now nothing left for him to do but to fold the robes of half a century's labors and honors around him and watch the descending sun. No, rest was not for him. He would work while his pulse beat, and he planned to open a free school at Nantucket for the instruction of all who wished to avail themselves of its privileges, in the investigation of living objects. Mr. Anderson, of New York, heard of his purpose and generously presented him with the island Penikese for the purpose. Agassiz unhesitatingly accepted the princely offer; he could not let the golden opportunity pass. His friends were troubled. But his enthusiasm sustained his diseased frame and carried it through the exhausting labors and excitements of the work. Sometimes his weakness conquered his resolution, and then he said, "I want rest; I am ready to go; I am tired!" Great soul! No wonder thou wast tired! No wonder thou didst pine for rest! "But," he continues, "I will work while I live. While I have strength I will labor;" and he arranged courses of lectures and series of investigations, and announced that he desired to die with the harness all on, the dust on his sandals, the word on his lip, the sketch on the blackboard, the object under the glass. And his prayer was answered. His first article of a long serieswas going through the press; tickets were sold for his lectures in New Haven, New York, and Washington. He had just returned to his home from his favorite laboratory in his museum, and—the curtain fell; not thick and impenetrable, but thin and translucent; and for a few days slight communications passed, and then all was still. Agassiz was dead! Nay, not dead. He was translated to fields whose glory and luxuriance will furnish opportunities of research which no gorgeousness of tropical abundance can rival. Every living thing has lost a friend, an interpreter; every student of nature a guide and inspirer.

Such is a *glimpse* of the gigantic labor which this devoted student performed; such is a *hint* of the success which he achieved. It would be difficult to tell which most kindled his enthusiasm, *obtaining* or *imparting* knowledge. How his face shone, how his whole massive frame trembled, when he discovered some new phenomenon! How his eyes beamed when he narrated his discovery! I have heard him pour out the

stores of knowledge derived from new investigations before the savants of this continent with the simplicity and self-forgetfulness with which a child would pour its toys into your lap; and I have heard him talk with apparently equal interest before a company of farmers and mechanics, whose knowledge of nature was almost infinitesimal. Yet he was most exacting of his students, sometimes even to a discouraging severity. He would say, "There is the subject, there are the tools; tell me what you can learn about it." Perhaps the severity of his own methods prevented his fully sympathizing always with the struggling, discouraged student. But one thing is clear, those who survived the fiery ordeal are among the foremost in their departments everywhere; and if they carry scars of their hard warfare, they are not of shame but of honor. They are all in front.

One of the most marked features of Agassiz's mind was its tendency to discover analogies, relations. Severe as was his scrutiny of particulars, marking the slightest variation from the typical form, things were not independent and unrelated, but parts of one great whole. His generalizations were as comprehensive as his examinations were minute. He saw system, provision, adaptation, everywhere. He had so penetrated the divine purpose, he had become so imbued with the methods and the forms of nature, that he could draw a whole from any part of a figure, and predict the image of an inhabitant of an unexamined zone or stratum. This ability, partly natural, partly acquired, enabled Agassiz to perform marvels in discovery. A solitary scale of a new species of fish was found in the fossiliferous rocks of Scotland. As no naturalist of the island could determine, and hence delineate, the species of fish to which the scale belonged, it was sent to Agassiz, then residing in his home in Switzerland, to see if he could construct the fish from the scale, giving its size, form, and probable habits. He examined the scale; determined what the size and form of the fish must have been; made a drawing of it; gave a full description of its habits; and returned the scale with his monograph and drawing to Scotland. Now it so happened that while Agassiz in his study in the shadow of the Alps was constructing this fish from a single scale, and describing its habits, a whole impression was found of a fish of the same kind or species as that whose scale had been sent to him. The Scotch naturalists were excited with intensest curiosity to learn whether he, with a single scale, would be able to correctly draw and describe the fish. What was their mingled delight and astonishment on opening his communication to find that he had so accurately figured and described the fish that hardly a line of his drawing needed to be erased or changed that it might conform to the original recently found.

Not only was his knowledge of the structure of fishes so perfect as to enable him, from a single scale, to construct the whole fish, but his knowledge of the period in which the different families and species of fishes existed upon the earth was such, so accurate, so minute, that he

could predict the kind of fish whose remains would be found in any given deposit or stratum should the discovery of any such fossil be made. A remarkable instance of his sagacity in this respect is related of him when, in early life, he visited England by invitation of the British Association for the Promotion of Science, to attend the annual meeting of its most eminent scholars. The students of the natural sciences in the island determined to put his knowledge of comparative zoology to the test, and to a crucial one. A fossil fish had very recently been found in a rock which was so low in the series that it was not supposed that any organic remains were deposited in it, and it had been classed with the azoic rocks. Agassiz was not aware, of course, that any such discovery had been made. At one of the sessions of the section in ichthyology, one of the members, in the course of the discussion, asked him what the structure and habits of the fish of that period would probably be if any remains should ever be discovered in the rocks then deposited. Agassiz was silent for a moment, and then, after a few suggestions in regard to the order observed in creation as known, he stated in a few words what he believed the size and structure of the fish would be, and, stepping to the blackboard, and taking the crayon, with a few hasty strokes he drew the form and general structure and appearance of the fish of that age, should it, indeed, be discovered; the *possible fish* which the harmony of nature would demand. After he had finished his sketch and taken his seat, what was the mingled surprise and delight of the members of the section not in the secret, when one of them stepped forward and removed a screen from the wall, revealing the tablet on which was the fossil, of just such proportions, of just such form, of just such structure as the one that Agassiz had drawn upon the blackboard. To such an extent had this great scientist advanced in a knowledge of the plan of God in nature.

He was eminently a religious and a devout man. He was ever looking for the indications of thought and purpose in nature from monad to mastodon. He studied nature as the work of an intelligent mind, not of blind forces. The more he discovered of order, the more he perceived of intellect. This vast display of animate and inanimate nature was to him the result and perpetual expression of the *divine thought*, *a revelation of God*. How I have seen his face glow as he described some of the most striking of the evidences of intellectual action in nature! He has been accused of weakness for yielding to such impressions, advancing such opinions. It was his great glory not to esteem the *thing* above the *thought*, the *product* above the *producer*. To see behind adapted forms a purposing mind is not a weakness, but a necessity for every comprehensive mind. The studies of Agassiz did not lead him into the mire of materialism nor the deserts of pantheism nor the dreary solitudes of atheism, but to the sublime ideas of God and immortality.

Yes; Agassiz was reverent. Said he to his class at Penikese, "The study of nature is direct intercourse with the highest mind. It is

unworthy an intelligent being to trifle with the works of the Creator. A laboratory of natural history is a *sanctuary*, in which nothing improper should be exhibited. I would tolerate improprieties in a church as soon as in a scientific laboratory" and in this spirit he did his work. May the same pervade all the investigations of his pupils and compeers!

Behind all his eminent attainments in science, Agassiz stood one of nature's noblemen, equally at ease in the presence of emperors and peasants; he could speak a word that would charm a child or delight a philosopher. He was too great to be distant from any one. Only littleness is distant, inaccessible. With what pitying sympathy would he listen to the story of the perplexed and discouraged inquirer, and how his words of instruction sent him away joyous as the morning!

Did he sometimes err? In the midst of his million cares and crushing burdens was he sometimes severe, merciless, if you please, in his exactions? Remember that with all his marvelous attainments, and yet more marvelous capacities to attain, he was still a man of like passions with us. But as a man he was such a one as we shall not soon look on his like again. The memory of hours spent with him will be evermore precious. The sweet tones of that musical voice will linger long in many a hall and laboratory and heart.

Of the value of many of his theories it does not become me to speak. They must be tried in the furnace of freest and fullest investigation. But however many of them may be proved to be dross, enough, I doubt not, will come out of the trial approved, to place him in the rank of the great discoverers of the nineteenth century. And American scientists will now with one consent proclaim that his instruction and enthusiasm have inspired and guided our students so that from his arrival on these shores a new scientific era may be dated. And American theologians, those whose blind eyes do not need cleansing in some Siloam, will confess with grateful hearts their obligations to one who has opened to them the great volume of nature, and taught them to read it reverently. And finally, when over his grave, amid the fragrance and glories of Mount Auburn, his monument is erected, let it be a column entwined with wreaths and symbols of his life's work, and on it there be inscribed, "THE INTERPRETER OF NATURE, WHO LOOKED FROM NATURE UP TO NATURE'S GOD."

SKETCH OF THE LIFE AND LABORS OF PROF. JOHN TORREY,

OF

COLUMBIA COLLEGE, NEW YORK, UNITED STATES ASSAYER, AND FOR MANY YEARS AN ESTEEMED COLLABORATOR OF THE SMITHSONIAN INSTITUTION.

BY DR. ASA GRAY, OF HARVARD COLLEGE.*

John Torrey, M. D., LL. D., died at New York on the 10th of March, 1873, in the seventy-seventh year of his age. He has long been the chief of American botanists, and was at his death the oldest, with the exception of the venerable ex-president of the American Academy, (Dr. Bigelow,) who entered the botanical field several years earlier, but left it to gather the highest honors and more lucrative rewards of the medical profession about the time when Doctor Torrey determined to devote his life to scientific pursuits.

The latter was of an old New England stock, being, it is thought, a descendant of William Torrey, who emigrated from Combe St. Nicholas, near Chard, in Somersetshire, and settled at Weymouth, Mass., about the year 1640.†

His grandfather, John Torrey, with his son William, removed from Boston to Montreal at the time of the enforcement of the "Boston port bill." But neither of them was disposed to be a refugee; for the son, then a lad of seventeen years, ran away from Canada to New York, joined his uncle, Joseph Torrey, a major of one of the two light infantry regiments of regulars (called Congress's Own) which were raised in that city; was made an ensign, and was in the rear-guard of his regiment on the retreat to White Plains; served in it throughout the war with

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* From the proceedings of the American Academy of Arts and Sciences.

† In some notes furnished by a member of the family, the descent is endeavored to be traced through the eldest of the five sons who survived their parent, namely, Samuel, who came with him from England, became a minister of the Gospel, and had the unprecedented honor of preaching three election-sermons (in 1674, 1683, and 1695) as well as of having three times declined the presidency of Harvard College, (after Hoar, after Oakes, and after Rogers.) Although educated at the college, he was not a graduate, because he left it in 1650, after three years' residence, just when the term for the A. B. degree was lengthened to four years. The tradition has it that, "at the prayer-meetings of the students he was generally invited to make the concluding prayer," for which an obvious reason suggests itself, for "such was his devotion of spirit that, after praying for two hours, the regret was that he did not continue longer." Students of the present day are probably less exacting.

The desire to claim a descent through so eminent a member of the family is natural. But our late venerable associate, Mr. Savage, in his Dictionary of Early New England Families, states that he could not ascertain that Samuel had any children.

honor, and until at the close he re-entered the city upon "Evacuation Day," when he retired with the rank of captain. Moreover, the father soon followed the son, and became quartermaster of the regiment. Captain Torrey, in 1791, married Margaret Nichols, of New York.

The subject of this biographical notice was the second of the issue of this marriage, and the oldest child who survived to manhood. He was born in New York on the 15th of August, 1796. He received such education only as the public schools of his native city then afforded, and was also sent for a year to a school in Boston. When he was fifteen or sixteen years old, his father was appointed fiscal agent of the state-prison at Greenwich, then a suburban village, to which the family removed.

At this early age he chanced to attract the attention of Amos Eaton, who soon afterward became a well-known pioneer of natural science, and with whom it may be said that popular instruction in natural history in this country began. He taught young Torrey the structure of flowers and the rudiments of botany, and thus awakened a taste and kindled a zeal which were extinguished only with his pupil's life. This fondness soon extended to mineralogy and chemistry, and probably determined the choice of a profession. In the year 1815, Torrey began the study of medicine in the office of the eminent Dr. Wright Post, and in the College of Physicians and Surgeons, in which the then famous Dr. Mitchell and Dr. Hosack were professors of scientific repute, he took his medical degree in 1818; opened an office in his native city; and engaged in the practice of medicine with moderate success, turning the while his abundant leisure to scientific pursuits, especially to botany. In 1817, while yet a medical student, he reported to the Lyceum of Natural History—of which he was one of the founders—his Catalogue of the Plants growing spontaneously within thirty miles of the city of New York, which was published two years later; and he was already, or very soon after, in correspondence with Kurt, Sprengel, and Sir James Edward Smith abroad, as well as with Elliott, Nuttall, Schweinitz, and other American botanists. Two mineralogical articles were contributed by him to the very first volume of the American Journal of Science and Arts, (1818–'19,) and several others appeared a few years later in this and in other journals.

Elliott's sketch of the botany of South Carolina and Georgia was at this time in course of publication, and Dr. Torrey planned a counterpart systematic work upon the botany of the Northern States. The result of this was his "Flora of the Northern and Middle Sections of the United States, *i. e.*, North of Virginia," which was issued in parts, and the first volume concluded in the summer of 1824. In this work Dr. Torrey first developed his remarkable aptitude for descriptive botany, and for the kind of investigation and discrimination, the tact and acumen, which it calls for. Only those few—now, alas! very few—surviving botanists who used this book through the following years can at all

appreciate its value and influence. It was the fruit of those few but precious years which, seasoned with pecuniary privation, are in this country not rarely vouchsafed to an investigator, in which to prove his quality before he is haply overwhelmed with professional or professorial labors and duties.

In 1824, the year in which the first volume (or nearly half) of his Flora was published, he married Miss Eliza Robinson Shaw, of New York, and was established at West Point, having been chosen professor of chemistry, mineralogy, and geology in the United States Military Academy. Three years later he exchanged this chair for that of chemistry and botany (practically that of chemistry only, for botany had already been allowed to fall out of the medical curriculum in this country) in the College of Physicians and Surgeons, New York, then in Barclay street. The Flora of the Northern States was never carried further, although a "Compendium," a pocket-volume for the field, containing brief characters of the species which were to have been described in the second volume, along with an abridgment of the contents of the first, was issued in 1826. Moreover, long before Dr. Torrey could find time to go on with the work, he foresaw that the natural system was not much longer to remain, here and in England, an esoteric doctrine, confined to profound botanists, but was destined to come into general use, and to change the character of botanical instruction. He was himself the first to apply it in this country in any considerable publication.

The opportunity for this, and for extending his investigations to the Great Plains and the Rocky Mountains on their western boundary, was furnished by the collections placed in Dr. Torrey's hands by Dr. Edwin James, the botanist of Major Long's expedition in 1820. This expedition skirted the Rocky Mountains belonging to what is now called Colorado Territory, where Dr. James, first and alone, reached the charming alpine vegetation, scaling one of the very highest summits, which from that time and for many years afterward was appropriately named James's Peak; although it is now called Pike's Peak, in honor of General Pike, who long before had probably seen but had not reached it.

As early as the year 1823, Dr. Torrey communicated to the Lyceum of Natural History descriptions of some new species of James's collection, and in 1826 an extended account of all the plants collected, arranged under the natural orders. This is the earliest treatise of the sort in this country, arranged upon the natural system; and with it begins the history of the botany of the Rocky Mountains, if we except a few plants collected early in the century by Lewis and Clark, where they crossed them many degrees farther north, and which are recorded in Pursh's Flora. The next step in the direction he was aiming was made in the year 1831, when he superintended an American reprint of the first edition of Lindley's Introduction to the Natural System of Botany, and appended a catalogue of the North American genera arranged according to it.

Dr. Torrey took an early and prominent part in the investigation of

the United States species of the vast genus *Carex*, which has ever since been a favorite study in this country. His friend, Von Schweinitz, of Bethlehem, Pa., placed in his hands and desired him to edit, during the author's absence in Europe, his monograph of North American Carices. It was published in the Annals of the New York Lyceum, in 1825, much extended, indeed almost wholly rewritten, and so much to Schweinitz's satisfaction that he insisted that this classical monograph "should be considered and quoted in all respects as the joint production of Dr. Torrey and himself." Ten or eleven years later, in the succeeding volume of the Annals of the New York Lyceum, appeared Dr. Torrey's elaborate monograph of the other North American Cyperaceæ, with an appended revision of the Carices, which meanwhile had been immensely increased by the collections of Richardson, Drummond, &c., in British and Arctic America. A full set of these was consigned to his hands for study (along with other important collections) by his friend, Sir William Hooker, upon the occasion of a visit which he made to Europe in 1833. But Dr. Torrey generously turned over the Carices to the late Professor Dewey, whose rival Caricography is scattered through forty or fifty volumes of the American Journal of Science and Arts; and so had only to sum up the results in this regard, and add a few southern species at the close of his own monograph of the order.

About this time, namely, in the year 1836, upon the organization of a geological survey of the State of New York upon an extensive plan, Dr. Torrey was appointed botanist, and was required to prepare a flora of the State. A laborious undertaking it proved to be, involving a heavy sacrifice of time, and postponing the realization of long-cherished plans. But in 1843, after much discouragement, the Flora of the State of New York, the largest if by no means the most important of Dr. Torrey's works, was completed and published, in two large quarto volumes, with one hundred and sixty-one plates. No other State of the Union has produced a flora to compare with this. The only thing to be regretted is that it interrupted, at a critical period, the prosecution of a far more important work.

Early in his career, Dr. Torrey had resolved to undertake a general flora of North America, or at least of the United States, arranged upon the natural system, and had asked Mr. Nuttall to join him, who, however, did not consent. At that time, when little was known of the regions west of the valley of the Mississippi, the ground to be covered and the materials at hand were of comparatively moderate compass; and in aid of the northern part of it, Sir William Hooker's Flora of British America—founded upon the rich collections of the Arctic explorers, of the Hudson Bay Company's intelligent officers, and of such hardy and enterprising pioneers as Drummond and Douglas—was already in progress. At the actual inception of the enterprise, the botany of Eastern Texas was opened by Drummond's collections, as well as that of the coast of California by those of Douglas, and after-

ward those of Nuttall. As they clearly belonged to our own phyto-geographical province, Texas and California were accordingly annexed botanically before they became so politically.

While the field of botanical operations was thus enlarging, the time which could be devoted to it was restricted. In addition to his chair in the medical college, Dr. Torrey had felt obliged to accept a similar one at Princeton College, and to all was now added, as we have seen, the onerous post of State botanist. It was in the year 1836 or 1837 that he invited the writer of this notice—then pursuing botanical studies under his auspices and direction—to become his associate in the Flora of North America. In July and in October, 1838, the first two parts, making half of the first volume, were published. The great need of a full study of the sources and originals of the earlier-published species was now apparent; so, during the following year, his associate occupied himself with this work in the principal herbaria of Europe. The remaining half of the first volume appeared in June, 1840. The first part of the second volume followed in 1841; the second in the spring of 1842; and in February, 1843, came the third and the last; for Dr. Torrey's associate was now also immersed in professorial duties and in the consequent preparation of the works and collections which were necessary to their prosecution.

From that time to the present the scientific exploration of the vast interior of the continent has been actively carried on, and in consequence new plants have poured in year by year in such numbers as to overtask the powers of the few working botanists of the country, nearly all of them weighted with professional engagements. The most they could do has been to put collections into order in special reports, revise here and there a family or a genus monographically, and incorporate new materials into older parts of the fabric, or rough-hew them for portions of the edifice yet to be constructed. In all this, Dr. Torrey took a prominent part down almost to the last days of his life. Passing by various detached and scattered articles upon curious new genera and the like, but not forgetting three admirable papers published in the Smithsonian Contributions to Knowledge, (*Plantæ Fremontianæ*, and those on *Batis* and *Darlingtonia*,) there is a long series of important, and some of them very extensive, contributions to the reports of Government explorations of the western country, from that of Long's expedition, already referred to, in which he first developed his powers, through those of Nicollet, Fremont, and Emory, Sitgreaves, Stansbury, and Marcy, and those contained in the ampler volumes of the surveys for Pacific Railroad routes, down to that of the Mexican boundary, the botany of which forms a bulky quarto volume of much interest. Even at the last, when he rallied transiently from the fatal attack, he took in hand the manuscript of an elaborate report on the plants collected along our Pacific coast in Admiral Wilkes's celebrated expedition, which he had prepared fully a dozen years ago, and which (except as to the plates) remains still un-

published through no fault of his. There would have been more to add, perhaps of equal importance, if Dr. Torrey had been as ready to complete and publish, as he was to investigate, annotate, and sketch. Through undue diffidence and a constant desire for a greater perfection than was at the time attainable, many interesting observations have from time to time been anticipated by other botanists.

All this botanical work, it may be observed, has reference to the flora of North America, in which, it was hoped, the diverse and separate materials and component parts, which he and others had wrought upon, might some day be brought together in a completed system of American botany.

It remains to be seen whether his surviving associate of nearly forty years will be able to complete the edifice. To do this will be to supply the most pressing want of the science, and to raise the fittest monument to Dr. Torrey's memory.

In the estimate of Dr. Torrey's botanical work, it must not be forgotten that it was nearly all done in the intervals of a busy professional life; that he was for more than thirty years an active and distinguished teacher, mainly of chemistry, and in more than one institution at the same time; that he devoted much time and remarkable skill and judgment to the practical applications of chemistry, in which his counsels were constantly sought and too generously given; that when, in 1857, he exchanged a portion, and a few years later, the whole, of his professional duties for the office of United States assayer, these requisitions upon his time became more numerous and urgent.* In addition to the ordinary duties of his office, which he fulfilled to the end with punctilious faithfulness, (signing the last of his daily reports upon the very day of his death, and quietly telling his son and assistant that he need not bring him any more,) he was frequently requested by the head of the Treasury Department to undertake the solution of difficult problems, especially those relating to counterfeiting, or to take charge of some delicate or confidential commission, the utmost reliance being placed upon his skill, wisdom, and probity.

In two instances these commissions were made personally gratifying, not by pecuniary payment, which, beyond his simple expenses, he did not receive, but by the opportunity they afforded to recruit failing health and to gather floral treasures. Eight years ago he was sent by the Treasury Department to California by way of the Isthmus; last summer he went again across the continent; and in both cases enjoyed the

* It ought to be added that, when the Government assay-office at New York was established, the Secretary of the Treasury selected Dr. Torrey to be its superintendent, which would have given to the establishment the advantage of a scientific head. But Dr. Torrey resolutely declined the less laborious and better paid post, and took in preference one the emoluments of which were much below his worth and the valuable extraneous services he rendered to the Government, simply because he was unwilling to accept the care and responsibility of treasure.

rare pleasure of viewing in their native soil, and plucking with his own hands, many a flower which he had himself named and described from dried specimens in the herbarium, and in which he felt a kind of paternal interest. Perhaps this interest culminated last summer, when he stood on the flank of the lofty and beautiful snow-clad peak to which a grateful former pupil and ardent explorer, ten years before, gave his name, and gathered charming alpine plants which he had himself named fifty years before, when the botany of the Colorado Rocky Mountains was first opened. That age and fast-failing strength had not dimmed his enjoyment may be inferred from his remark, when, on his return from Florida the previous spring, with a grievous cough allayed, he was rallied for having gone to seek Ponce de Leon's Fountain of Youth. "No," said he, "give me the Fountain of Old Age. The longer I live the more I enjoy life." He evidently did so. If never robust, he was rarely ill, and his last sickness brought little suffering and no diminution of his characteristic cheerfulness. To him, indeed, never came the "evil days" of which he could say, "I have no pleasure in them."

Evincing in age much of the ardor and all of the ingenuousness of youth, he enjoyed the society of young men and students, and was helpful to them long after he ceased to teach, if, indeed, he ever did cease; for, as Emeritus Professor in Columbia College, (with which his old medical school was united,) he not only opened his herbarium, but gave some lectures almost every year, and as a trustee of the college for many years he rendered faithful and important service. His large and truly invaluable herbarium, along with a choice botanical library, he several years ago made over to Columbia College, which charges itself with its safe preservation and maintenance.

Dr. Torrey leaves three daughters, a son, who has been appointed United States assayer in his father's place, and a grandson.

This sketch of Dr. Torrey's public life and works, which it is our main duty to exhibit, would fall short of its object if it did not convey, however briefly and incidentally, some just idea of what manner of man he was. That he was earnest, indefatigable, and able, it is needless to say. His gifts as a teacher were largely proved, and are widely known through a long generation of pupils. As an investigator, he was characterized by a scrupulous accuracy, a remarkable fertility of mind, especially as shown in devising ways and means of research, and perhaps by some excess of caution.

Other biographers will doubtless dwell upon the more personal aspects and characteristics of our distinguished and lamented associate. To them, indeed, may fittingly be left the full delineation and illustration of the traits of a singularly transparent, genial, delicate and conscientious, unselfish character, which beautified and fructified a most industrious and useful life, and won the affection of all who knew him. For one thing, they cannot fail to notice his thorough love of truth for its own sake, and his entire confidence that the legitimate results of sci-

entific inquiry would never be inimical to the Christian religion, which he held with an untroubled faith, and illustrated most naturally and unpretendingly in all his life and conversation. In this, as well as in the simplicity of his character, he much resembled Faraday.

Dr. Torrey was an honorary or corresponding member of a goodly number of the scientific societies of Europe, and was naturally connected with all prominent institutions of the kind in this country. He was chosen into the American Academy in the year 1841. He was one of the corporate members of the National Academy at Washington. He presided in his turn over the American Association for the Advancement of Science. He was twice, for considerable periods, president of the New York Lyceum of Natural History, which was in those days one of the foremost of our scientific societies. It has been said of him that the sole distinction on which he prided himself was his membership in the Order of the Cincinnati, the only honor in this country which comes by inheritance.

As to the customary testimonial which the botanist receives from his fellows, it is fortunate that the first attempts were nugatory. Almost in his youth a genus was dedicated to him by his correspondent Sprengel: this proved to be a *Clerodendron*, misunderstood. A second, proposed by Rafinesque, was founded on an artificial dismemberment of *Cypreus*. The ground was clear, therefore, when, thirty or forty years ago, a new and remarkable evergreen tree was discovered in our own Southern States, which it was at once determined should bear Dr. Torrey's name. More recently a congener was found in the noble forests of California. Another species had already been recognized in Japan, and lately a fourth in the mountains of Northern China. All four of them have been introduced, and are greatly prized as ornamental trees in Europe; so that, all round the world, *Torreya taxifolia*, *Torreya Californica*, *Torreya nucifera*, and *Torreya grandis*—as well as his own important contributions to botany, of which they are a memorial—should keep our associate's memory as green as their own perpetual verdure.

A MEMORIAL OF GEORGE GIBBS.

By John Austin Stevens, Jr.

[The subject of the following memorial, George Gibbs, was for many years an active collaborator of the Smithsonian Institution, especially in the line of ethnology. He had charge of all the Indian vocabularies which had been collected by the Institution, and was preparing them for publication at the time of his death. The valuable and laborious service which he rendered to this Institution was entirely gratuitous, and in his death this establishment as well as the cause of science lost an ardent friend and important contributor to its advancement. The following tribute to his memory, by John A. Stevens, jr., read before the New York Historical Society, October 7, 1873, finds a proper place for republication in the annual report of this institution to which he rendered such signal service.—J. H.]

George Gibbs, so long familiar to the members of this society as its unwavering and faithful friend, and for many years its librarian and custodian, has passed from the scenes of his busy and useful life to that sphere in which all histories of this finite existence find their sum and complement.

The son of Col. George Gibbs, of the Newport, R. I., family of that name, and of Laura Wolcott, he was born on the 17th July, 1815, at Sunswick, Long Island, near the village of Hallett's Cove, now known as Astoria. His father was a man of singular culture and talent. Brilliant in conversation, polished in manners, and of large and various experience of men and life, Colonel Gibbs was one of the marked men of his day, and his large mansion at Sunswick was the seat of a broad and elegant hospitality rarely to be met with in this country at that time. As an instance of the extent of this hospitality, it may be stated that during the cholera-summer of 1832 several families found refuge here and at the lodge during the whole time of the pestilence. The beautiful mansion, with its front upon the East River at one of its most picturesque points, and its rear opening upon a broad inward landscape of fertile farm-fields, was then one of the landmarks of the river. And its stone descent from the terrace to the shore still marks the old house, which is now occupied as the Convent of the Sacred Heart. In Colonel Gibbs's day, fine horses and dogs were always to be found about a gentleman's residence. Passionately fond of field-sports, he was constantly at the south side of Long Island, where deer and small game were then the certain reward of the day's hunt, and his son was often his companion. For access to the city, he had for years a small yacht, which he styled the Laura. His gardens were celebrated for the character and abundance of their splendid crops. To these, as to all that he touched,

Colonel Gibbs brought the resources of his well-stored mind. Within was his fine library, abounding in the works of the best authors, and in many tongues; added to this, a mineralogical collection. It may be here mentioned that the extensive and valuable collection now in the possession of Yale College was made by Colonel Gibbs himself while abroad. These incidents in the life of the father are alluded to here as having a direct bearing upon the career of the son.

The mother of George Gibbs was Laura Wolcott, daughter of Oliver Wolcott, the Secretary of the Treasury under Washington and the elder Adams, one of the fathers of the country. It is not needful in this city, where her true, brave character, her well-stored and independent mind are still fresh in remembrance, to dwell upon the influence of such training upon her rising family. The original purpose of Colonel Gibbs was to give his son a West Point education and to fit him for an army career; this and the navy were at that time considered as the only true occupations for the sons of gentlemen. As a preliminary step he was sent to the Round Hill School, at Northampton, Mass., then kept by Mr. George Bancroft, the historian, and Mr. Cogswell, the late learned and distinguished superintendent of the Astor Library. At seventeen, it having been found impossible to secure for the youth an appointment to the Military Academy—political favor then, as now, being indispensable to success—he was taken to Europe by his maiden aunt, Miss Sarah Gibbs, and for two years enjoyed the advantage of foreign travel, observation, and study, the influence of which upon his education and character was never lost. Though the family were disappointed in their wish to enter the eldest son as a military student, their efforts were not relaxed; as the one grew beyond the age at which alone the candidate is eligible, the claim for an appointment was transferred to the next son, and as persistently urged. Those who know the family on both sides of the house know of the unwavering determination with which they press to the point in view. The second son, in turn, was compelled to give up his ambition, and entered Columbia College, to take high rank as a scholar, and is now well known as the professor of chemistry at Harvard College. Later, a third son, the late Maj. Gen. Alfred Gibbs, received the long-sought commission, and history has already inscribed his gallant deeds on her imperishable scroll.

On his return from Europe, George Gibbs commenced the reading of law, and in 1838 took his degree of bachelor of law at Harvard University. His first essay in literature was here made. In 1834, the very year of his entrance, he published, at Cambridge, a work entitled "The Judicial Chronicle, being a list of the judges of the courts of common law and chancery in England and America, and of the contemporary reports from the earliest period of the reports to the present time," in octavo. On his return to New York he entered the law-office of the late Prescott Hall, and by degrees attached himself to his profession and engaged in such practice as he could obtain. With this agreeable

and genial gentleman he continued the most friendly and intimate relations until his death. A great part of his time, however, he passed in the country. His early taste for an out-door life always clung to him. Shooting and fishing were his favorite amusements, diversified with a practical and useful attention to geology and natural history. When the family removed to the city from Sunswick, in 1835, he had already made and mounted with his own hands a large collection of birds, and he had also gathered together a considerable mineralogical cabinet. The latter he sent to New Haven, as a gift to be added to his father's collection. These early tastes mark the natural tendency of his mind, and his whole career shows how strongly they were implanted in his nature; how foreign to his general intellectual bias must have been the plodding and confinement of the study of the law. Early he seems to have made his election as between science and law, although the crippled condition in which his father's death left the family estates did not allow of his deserting that profession which he had adopted and to which he looked for his own support. Nor could he ever have contented himself with the dry study of Blackstone and Chitty, or any other of the law worthies. His taste for literature was too catholic for this, and his intellectual rambles about his father's library had opened too many vistas of charming pasturage for him to stay his appetite with the dry food of legal disquisition. He showed this taste even in the practice of his profession. He gave himself up with hearty zeal to the historical branch of conveyancing, and made valuable collections of titles and abstracts in this department of law.

George Gibbs loved literature. He was familiar with all the good old books which our fathers were wont to read. He loved the strong and Saxon language of the earlier day—of Latimer and Hall, of Swift and Sterne, of Bolingbroke and Shaftesbury. The cast of his mind was puritanic in its stern hatred of new-fangled notions and new-fashioned phrases. He loved with his grand sonorous voice to roll out the verses of the old covenanter hymns or the paraphrases of the psalms of Sir Philip Sydney, a "pure well of English undefiled." He loved politics also. Ardent in all that he engaged in, he soon found himself occupied in a history of the times of Washington and Adams, and a vindication of the policy of his grandfather as Secretary of the Treasury and a member of the cabinet of John Adams. The hot feud between the federalists and the republicans had not died out, and the young polemic took up the "burning brand," which in those days was indeed passed on from sire to son as thoroughly as ever by Scottish partisan in Scottish feud. To use his own words, Mr. Gibbs "felt himself not only the vindicator, but in some sort the avenger, of a by-gone party and a buried race."

This work occupied a great part of his time. He embraced in it the correspondence of Oliver Wolcott, and it stands to-day as a text-book of the history of the day—as an unquestioned authority upon the per-

sonages and the politics of that stirring period. It is written in strong, nervous style, with great clearness and simplicity. It is questionable whether at the time the publication of these volumes was of benefit to the young lawyer. The law in those days was supposed to allow of no divided suit for her favor, and literary lawyers received few briefs. This publication, under the title of "The Memoirs of the Administration of Washington and Adams, edited from the papers of Oliver Wolcott, Secretary of the Treasury," was printed in 1846, in two volumes octavo.

In 1848 an event occurred which strangely affected the minds of all those restless spirits who chafed under the confinement of city life, and yearned for the freedom of nature. Gold-fields were discovered in California. The wonders of the fifteenth century were renewed in the very current of our daily life, and a new El Dorado opened an inviting field for adventurous character. Dissatisfied with the dull routine of a sluggish practice, and urged on by his unwearied taste for practical scientific research, Mr. Gibbs took advantage of an occasion which the march of the Mounted Rifles overland from Saint Louis to California afforded him, and accompanied them to Oregon, where he established himself at Columbia.

Before he left New York he had taken a lively interest in politics, and was an active member of the whig party. Not a man to remain quiet when his feelings were aroused, he soon became prominent among men of the whig opinion, and was a leader in the councils of the young men's committee. When Mr. Fillmore succeeded to the Presidency of the United States, Mr. Gibbs received, in 1854, the appointment of collector of the port of Astoria, which he held during his administration. Later he removed from Oregon to Washington Territory, and settled upon a ranch a few miles from Fort Steilacoom, at a small settlement called by the same name. Here he had his headquarters for several years, devoting himself to the study of the Indian languages, and to the collection of vocabularies and traditions of the northwestern tribes. During a great part of the time he was attached to the United States Government commission in laying the boundary as the geologist or botanist of the expedition. Each commission in turn sought eagerly for the aid of his practical experience, his varied and extensive acquirements, and the comfort of his brave, cheerful, genial nature. He was specially attached as geologist to the survey of a railroad-route to the Pacific under Major (afterward General) Stevens. His associates on this expedition were Drs. George Suckley and J. G. Cooper as naturalists, to whose reports Mr. Gibbs made large contributions.

In 1857 he was appointed to the northwest boundary survey, under Mr. Archibald Campbell as commissioner, with General J. G. Parke as chief engineer, and after the close of the survey prepared an elaborate report on the geology and natural history of the country.

It must not be supposed that the life in Oregon in those days was a life of ease or leisure—rather a rude struggle with nature for even exist-

ence—weeks and months in the cold and heat, amid snows and rain, surrounded by the savage beasts of the forest, and exposed at times to the treacherous attacks of the wild Indian or the more dangerous whites, who, breaking loose from their frail attachment to society, spread over the Territories, and returned practically to the original state of man. Yet with all this there was a charm which none who have experienced it have ever forgotten; not alone "the pleasure in the pathless woods," nor yet the "society where none intrudes," but that intimate relation of man with man, of mind with mind, that fellowship, in the midst of solitude and danger, of a body of cultivated and intellectual men, all serving one common cause, and all impelled by one common impulse—that cause the prosperity of their native country—that impulse the love of science. He who has witnessed the meeting of those friends, most of them of West Point education—Army men all—has not failed to note with admiration—with which even regret mingled, that such was not his lot—the affectionate relations which neither time nor distance, nor the natural separation which life always brings, seemed sensibly to affect or weaken.

Many a one fell face to the foe in the dreadful struggle which brought every man home from his distant post. One by one they drop away and join the increasing column in that undiscovered country whose boundaries no human eye shall ever survey, and whose wonders no human tongue shall ever tell, where the pale-face and the red-man shall meet in brotherhood, and speak one common language. To the close of his life Mr. Gibbs continued warm friendships contracted amid these wild scenes. His intimacies were to a great extent with Army men, but his friends were in all ranks of society. Few men had such a large acquaintance as he, and few lived more loved and died more mourned. During his whole life at the West he never failed to write once or twice a week to his family. His letters are full of graphic description of life and nature, and should be published. No better contribution could be made to the history of the early days of these settlements.

In 1860, Mr. Gibbs returned to New York, not intending to remain permanently. Nature still whispered her tender song in his ear, and would no doubt have charmed him to her bidding but for the outbreak of the war. This brought with it other occupations and other duties. Too uncertain in health for continuous service, and even then laboring under the painful disease which finally brought him down, he threw himself, with his strong character, his great perseverance, and his abundant energy, into the service of the Union in another form. He was an early and active member of the Loyal National League, which did so much to crystallize public opinion in the second year of the war, and also of the Loyal Publication Society, which distributed such masses of tracts and healthy patriotic literature over the whole country. Of great personal bravery, he was always ready to expose life in defense of principle. In Washington, during the dark hours of March and April, 1861, he took his musket and went upon duty to guard the Capitol at the

first sign of danger. And in the New York riots he sought the place of greatest peril, and volunteered for the defense of the house of General Frémont, when a night attack was threatened. He was not a man to ask another to do that which he was not ready to do himself.

Later he resided in Washington, and was mainly employed in the Hudson Bay Claims Commission, to which he was secretary. He was also engaged in the arrangement of a large mass of manuscript bearing upon the ethnology and philology of the American Indians. His services were availed of by the Smithsonian Institution to superintend its labors in this field, and to his energy and complete knowledge of the subject it greatly owes its success in this branch of service.

He published, some years since, a series of the vocabularies of the Clammal, Lummi, and Chinook languages, and of the Chinook jargon, besides other tracts of a similar kind; and at the time of his death was engaged in superintending the printing for the Smithsonian Institution of a quarto volume of American Indian vocabularies, and had fortunately arranged and carefully criticised many hundred series before his death. This publication will continue under the direction of Prof. W. D. Whitney, J. H. Trumbull, LL. D., and Prof. Roehrig. His large collection of papers on the Indian languages, of translations of many and curious legends, all of incalculable value to science, has been bequeathed to the Smithsonian Institution, his numerous maps and charts to the Geographical Society, and such of his books as were suitable for the purpose to this society.

In 1871 Mr. Gibbs married his cousin, Miss Mary Kane Gibbs, of Newport, R. I., and removed to New Haven, where he died on the 9th of April, 1873. Though a great sufferer at times from a chronic disease of the most painful character, his last years were happy beyond the common lot. His house was celebrated for its simple, unaffected hospitality, and was the resort of a charming circle of refined and cultivated people.

To whatever work Mr. Gibbs was engaged he devoted his whole heart and every energy he possessed. This historical society owes its present prosperity as much to his aids as to those of any person. Its revival, in 1840, was largely owing to his determined efforts; its librarian for six years, from 1842 to 1848, and long a leading member of the executive committee and library committees, he never wearied in his efforts to promote its prosperity. Its frequenters have not forgotten his hale and hearty presence, his genial manner, his cheerful temper. Honest to the requirement of the ancient philosopher, generous to a fault, though in his varied life he had received but small aid from fortune, he was one of the warmest-hearted, most charitable of men. Who will soon forget his plain, outspoken, manly, and unvarnished speech, his indignant denunciation of wrong, his hatred of oppression? The edge of his speech did not always carry the polish of the scimitar, but its blow fell heavy as that of the battle-ax.

He was a man; truth was his element; no fraud or humbug throve in his society. He was as bold to expose as he was quick to see through false pretense. For this he was thought by some as uncompromising beyond reason. He had no enemies. He bore no malice. His was not a nature to see faults in others which were foreign to itself. His friendships were always warm; his antipathies were rarely personal. His faults were all those of a large, generous nature, such as one may look to find in the broad, deep-chested, short-statured man, whose large play of vital functions keeps him forever harshly busy until the whole machine breaks down in one crash.

How to speak of his domestic character! A more lovely nature never breathed. Many an eye moistened as it met the mournful notice of his death. Many a one felt that one of those true friends on whom absolute, entire reliance might always be placed, had gone and left a void there is no filling. One mourned him as a brother. Brotherless himself, he had been wont from early years to attach himself to this frank, noble nature. The attachment of the child for the youth strengthened into friendship as manhood found both on the same level, and through long years of personal intimacy when together and of correspondence when separated, that friendship remained unbroken by a word of quarrel, unshadowed by a look of unkindness. The survivor may be forgiven that, deprived by an ocean's breadth from the fulfillment of the last office of friendship to his more than kin, he pours out here an offering of memory and affection to his silent shade.

THE ORIGIN AND PROPAGATION OF DISEASE.

A discourse before the New York Academy of Medicine, with additions.

By John C. Dalton, M. D.

The anniversary meeting of the Academy of Medicine may be regarded as a sort of annual conference, in which one of its members is deputed to offer to the Academy a short address upon some topic of general professional interest, and more or less appropriate to the time. Perhaps we can hardly employ the occasion to-night in a more suitable way than by endeavoring to see what, on the whole, is the direction in which medical thought is now most active; to cast the professional horoscope, so to speak, for the present, and to anticipate, as nearly as may be, what we are to expect from it in the immediate future.

Not that we should be willing to claim the gift of prophecy or to place too much confidence in delusive flights of the imagination. Medicine is essentially a skeptical science, and very properly regards with disapproval anything which claims her attention without offering, at the same time, unmistakable guarantees of respectability. But there may be a kind of anticipation which is really a scientific one. Within the past two or three years we have seen our own Meteorological Bureau triumph over what was proverbially the most difficult of all popular puzzles, and foretell the weather of each day with a certainty which has excited our surprise and admiration. With telegraph-lines from all over the continent converging to the central office at Washington, the chief of the Bureau can trace, from hour to hour, the progress of a meteorological change, moving, with uniform or accelerated speed, from Saint Paul to Milwaukee, from Milwaukee to Detroit, from Detroit to Buffalo; and he knows that within a given period it will reach New York, with almost as much certainty as though he stood on the top of a watch-tower and saw it coming. Within such limits as these it may perhaps be allowable sometimes to indulge in surmises, even in the strictest and most exacting of the natural sciences.

Is there anything in the aspect and condition of any part of medicine to-day that looks like a change in the scientific barometer? Can we see such a tendency in the medical mind at present as would suggest what may fairly be called a new movement—in which successive ideas and discoveries are not only accumulating as heretofore, but in which they also seem to be taking, or about to take, a new interpretation; so as to

give expression, in definite terms, to a doctrine which has heretofore had only a vague and uncertain existence?

If there be any one direction in which progress is now so marked as to constitute a dominant feature of the present state of medicine, and to embrace a practically new medical idea, I should say it was that of the *origin and propagation of disease by independent organic germs.* Perhaps it would be wrong to say that this doctrine is even yet distinctly formulated. It is certainly far from being definitely established as a general truth. Some very wild and reckless statements have been made in regard to it by observers possessed of more zeal than knowledge; and some elaborate but baseless theories relating to the specific development and transformation of organic germs have been tried at the bar of scientific investigation, and, being convicted of incompetency, have suffered accordingly the just penalty of extermination. Perhaps the doctrine itself will also be finally abandoned. It may be that the evidence in its favor, which is yet only partial, will hereafter lose its special significance; and the appearances which now seem to sustain it may come to be naturally explained in some other way. Still there can be no doubt that the idea is at present entertained, and that it is by no means confined to the minds of careless or irresponsible theorizers. So far, it exists in the form rather of a scientific instinct than of a positive belief; and its gray light hangs about the edge of the medical horizon like the coming dawn of a new period.

Now, can this instinct of the medical mind be justified in any way? Are there any facts and discoveries, already established beyond the possibility of doubt, which have naturally led it in this direction, and which point, like the telegraphic reports of successive meteorological stations, to a continuous and definite movement of scientific pathology?

I think it really began many years ago, in the early investigation of parasitic diseases. Perhaps we can hardly include under this designation the effects produced by ordinary intestinal worms, like tænia or ascaris, because the animal and parasitic nature of these worms was perfectly palpable, and could not be mistaken by any one. But *scabies* was on a different footing. It was a contagious, eruptive affection, capable of spreading over a large portion of the body, and of giving the patient great discomfort; and, when it was found to be due simply to the presence and propagation of a parasitic insect, the discovery was a great achievement, and for the first time made it possible to have a distinct and rational comprehension of the origin of the disease, as well as of its propagation and means of cure. A remarkable circumstance in the history of our knowledge in regard to *Sarcoptes scabiei* is, that its discovery in the present century was in fact a rediscovery of something which had been known centuries before and long forgotten; or, at least, the method of finding the insect having been lost, the most eminent dermatologists of forty years ago had never seen it, and were really in doubt as to its existence. However, this uncertainty was terminated in

1834, by the Corsican student Renucci, and the study of its structure and development was afterward accomplished by Raspail and Bourguignon; so that our knowledge, both of the disease and its parasite, was then placed upon a permanent footing.

Perhaps the most suggestive part of this discovery related to the *reproduction* of the parasite, the manner in which the female lays her eggs in galleries excavated in the skin, and the time required for the hatching and dispersion of the young, because this showed a direct connection between the local spread of the disease and the increase, by ordinary sexual generation, of the young brood of the parasite. However, there was nothing very remarkable in the mode of this generation. The eggs of the female were deposited and hatched in the usual way, and the young *sarcoptes* came to resemble their parents after a very short and regular period of development.

But ten or fifteen years later a discovery was made with regard to some of the *internal* parasites which had a character of unexpected peculiarity; that was, the specific identity of two parasites formerly supposed to be distinct, namely, *cysticercus* and *tænia.* These two worms—so unlike in their size, their general configuration, and even in the species of animal which they inhabit—were shown by the researches of Siebold and Küchenmeister to be only different stages of growth of the same creature—one the encysted and quiescent, the other the intestinal and reproductive form. The well-known experiments carried on in this investigation showed furthermore the regular and natural conversion of these two forms into each other; and thus we came fully to understand that the existence of tape-worm in man was owing to his having eaten measly pork containing *cysticercus*, and that the pig became contaminated with *cysticercus* by devouring the eggs or the egg-bearing articulations of *Tænia solium.* The knowledge of the alternation of generations and of the migration of parasites from one habitat to another at different periods of their development became in this way connected with the pathology and mode of propagation of certain well-known and perfectly distinct morbid affections.

But so far, perhaps, these morbid affections hardly deserved the name of diseases. They were simply local disorders, due to the presence of a parasitic intruder in the substance of the skin or in the cavity of the intestinal canal. It was another thing to learn, some years later, that a microscopic parasite might diffuse itself generally throughout the system, and thus give rise to a rapid and fatal train of symptoms hardly distinguishable from those of any febrile constitutional disease. No doubt cases of infection by *Trichina spiralis* have always occurred as frequently as they do now. But previous to the year 1850 the milder ones in all probability were supposed to be rheumatic in their origin, while the fatal cases passed for fevers of a typhoid character. There were even epidemics of the trichinous affection, as there are of typhoid fever and influenza; and, when the true character of the disease be-

came known, it was perfectly evident how these epidemics originated and exactly how far they might extend. Each one was commenced by the slaughter and preparation for food of a trichinous pig; and the patients affected were precisely those who had introduced into their systems ever so small a portion of the infectious food.

In this instance, also, there was found to be an unexpected relation between two different forms of the same parasite. *Trichina spiralis* had been known since 1830; but it had yet been seen only in its quiescent, encysted form, embedded in the muscular tissue, without movement or reproduction. Consequently, though we were familiar with the worm itself, we knew nothing of the disease produced by it. Its new growth and active reproduction in the intestinal canal, the swarming emigration of its innumerable progeny, and the constitutional symptoms which followed, were a new revelation, and showed that the whole system, as well as a particular organ or tissue, might suffer from the effects of parasitic contamination.

In all the affections which have now been enumerated, the parasite is one of an animal nature, with regular generative apparatus and active sexual reproduction. But the last thirty years have seen a very remarkable advance also in our knowledge of the *vegetable* parasites. This has naturally coincided with a similar activity among scientific botanists in the study of the simpler forms of vegetation, the cryptogamic plants in general, and particularly of the microscopic fungi and algæ. A little over a half a century ago the species of flowering plants described by botanists were much more numerous than the cryptogams; but now the proportions of the two classes are reversed. In 1818, according to Mr. Cooke,* an eminent British botanist, "less than eighty of the more minute species of fungi, but few of which deserved the name of microscopic, were supposed to contain all then known of these wonderful organisms. Since that period microscopes have become very different instruments; and one result has been the increase of the 564 species of British fungi to 2,479. By far the greater number of the species thus added depend for their specific characters upon microscopical examination. At the present time the number of British species of flowering plants scarcely exceeds three-fourths of the number of fungi alone, not to mention ferns, mosses, algæ, and lichens."

A large proportion of these microscopic plants are parasitic upon other organisms; and for the earliest study of them, as connected with disease in the human subject, we are indebted to the dermatologists.

The first discovery of parasitic vegetation in cutaneous affections was by Schönlein, in 1839,† who found, in the crust of *favus*, cryptogamic vegetable filaments ramifying in the diseased growth. In 1841 Gruby made a similar observation,‡ and described accurately both the mycelium fila-

* "Introduction to the Study of Microscopic Fungi," London, 1870, p. 45.

† Muller's Archiv for 1839; cited in Robin's "Végétaux parasites," Paris, 1853, p. 477.

‡ "Comptes Rendus de l'Académie des Sciences," 1841, tome xiii, pp. 72, 309.

ments and the spores. He asserted them to be always present in cases of *favus*, and declared that the malady itself was essentially "nothing but a vegetation." The parasite thus described proved to be the same with that previously seen by Schönlein, and it was at last definitely known by the name of *Achorion Schönleinii.*

Gruby continued his examinations, and in 1844 discovered a microscopic vegetation growing upon the skin, in a case of *Porrigo decalvans;** and the same parasite, the *Trichophyton tonsurans*, has since been recognized as a constant accompaniment of *Tinea sycosis* and *Tinea circinnata.*

Finally, *Microsporon furfur* was discovered by Eichstedt, in 1846,† as a parasitic vegetation in *Tinea versicolor;* so that within seven or eight years three distinct microscopic fungi were discovered and recognized as occurring in diseased conditions of the human skin.

Now, the first question which naturally came up in relation to the discovery was this: Is the microscopic fungus the cause of the disease, or is the disease the cause of the fungus? Either of these two suppositions might be the true one. In the first place, the fungus, by its accidental presence and growth in the skin, might excite all the irritation and morbid discharges characteristic of the malady. On the other hand, its presence might be altogether secondary, and a result of the morbid action instead of its cause. Every vegetable requires a soil suited to its growth. The fungus-germs might be incapable of fastening themselves upon the healthy skin, but might readily flourish in the decomposing mixture of inflammatory exudations. This question, in the earlier stages of the investigation, presented a real difficulty. Henle, in 1840, believed that *Achorion Schönleinii* was merely an incidental formation in the crust of *favus*, while Remak and others regarded it as the cause and essential element of the disease.

Now, how was this difficulty to be settled? If *Tinea tonsurans* is always accompanied by *trichophyton*, and if *trichophyton* is never found upon the skin except in some form of *tinea*, how can we tell which of these two is the cause and which the consequence of the other?

The test of this is twofold: 1. Inoculation of the parasite and reproduction of the disease; 2. Destruction of the parasite and cure of the disease.

Both of these tests have been successfully carried out. The inoculation of *Achorion Schönlenii* was accomplished by Remak,‡ in 1840, and subsequently by Bennett,§ Hebra, Vogel, Bazin,|| Köbner and Deffis; that of *Trichophyton* by Deffis¶ and Köbner;** and, finally, that of

* "Comptes Rendus de l'Académie des Sciences," tome xviii, p. 583.

† Cited in Robin's "Végétaux parasites," Paris, 1853, p. 438.

‡ Cited in Robin; "Végétaux Parasites," Paris, 1853, p. 477.

§ "Principles and Practice of Medicine," New York, 1867, p. 850.

|| "Affections cutanées parasites," Paris, 1858, p. 56.

¶ Bazin, "Affections cutanées parasites," p. 147.

** Schmidt's "Jahrbücher," cxxvi, p. 260.

Microsporon, by Köbner,* in 1864. The fungus-spores, transplanted upon the skin of other individuals, or upon other parts of the skin of the patient, after a certain interval germinate and multiply, and so create a secondary focus of the disease. The contagious character of the malady is thus seen to depend, not upon a virus, in the old sense of the word, but upon the actual communication of reproductive germs, which give origin in their new location to a vegetative growth similar to the old. The vegetable growth, therefore, precedes the disease, and must be regarded as its cause rather than its consequence.

The actual transportation of these germs through the air is also a matter of demonstration. Lemaire† placed glass jars filled with ice in a shallow basin, so that the condensed moisture of the atmosphere, deposited upon the cold sides of the glass, might trickle down and collect in the basin below. He then applied friction to the head of a boy with *favus*, near by, and found that the spores of achorion were floated by the air-currents for a distance of twenty inches into contact with the jars; and then, being entangled by the condensed moisture, were carried down into the basin. He sometimes found as many as thirty spores in a single drop of condensed moisture.

The second part of the test is equally well established. I presume that dermatologists are now fully agreed that, for all cutaneous affections known to be characterized by the presence of a microscopic fungus, the one essential element of cure is the application of some parasiticide which shall destroy the vitality of the fungus. Iodine, sulphurous acid, or mercurial bichloride, by killing the vegetable, as sulphur-ointment kills the animal parasite of scabies, in simpler cases absolutely puts an end to the disorder, and in the more complicated ones leaves behind only secondary symptoms, which have no longer any specific or contagious character. Of course there are various points relating to these affections which are still more or less in doubt. Some microscopic cutaneous fungi have been described as distinct species, which have not received general recognition, and some observers are disposed to question whether the three principal ones may not all be simple varieties or forms of development of the same plant.

But there are similar points of difference still existing among scientific botanists with regard to microscopic fungi in general; and I believe that the three principal facts of (1) specific parasitic vegetation as a cause of cutaneous disease; (2) its propagation by the transport and germination of spores; and (3) its treatment and cure by parasiticide applications, may now be regarded as wholly beyond a reasonable doubt.

I have already alluded to the remarkable activity of botanical research of late years in the department of cryptogamic vegetation. The most striking results have been attained by these investigations, in increased knowledge of the modes of development and reproduction of these organ-

* Cited in Neumann's "Handbook of Skin-Diseases," translated byDr. L. D. Bulkley, New York, 1872, p. 434.

† "Comptes Rendus de l'Académie des Sciences," 1864, tome lix, p. 127.

isms. The phenomena of the so-called alternation of generations and of migration from one habitat or locality to another, are by no means confined to animal parasites. On the contrary, the most remarkable instances of both are to be found in cryptogamic vegetables. Fungi formerly regarded as distinct species, and even as belonging to different genera are seen to be successive forms of the same plant, following each other in definite order through the regular cycle of their annual reproduction.

The three fungi, known as *Trichobasis*, *Puccinia*, and *Æcidium*, appear in succession, as different members of the same specific generation, upon the cereal grains in summer and in autumn, and upon the barberry in the spring; while corresponding differences are to be seen in their spores and mode of germination at these different epochs.

It would perhaps be difficult to imagine a scientific pursuit less likely to produce anything of value for practical medicine than the study of microscopic fungi growing as parasites upon other vegetables. And yet, if it should finally turn out that these minute researches are preliminary to the discovery of a means for preventing or controlling an epidemic of scarlatina, we can say with truth that such a result would not be more remarkable than many which have actually followed from purely scientific investigations in chemistry and physics.

At all events, it is certain that these botanical discoveries have had an important influence in directing medical research in the path which it is now following. It could hardly be otherwise, from the moment they were found to have a direct connection with certain epidemic diseases in the vegetable world, some of which are of great practical consequence to us as affecting the annual supply of food.

Let me remind you of the history of our knowledge in regard to the disease known as the *potato-rot.*

This disease first made its appearance, so far as we know, about thirty years ago. The most destructive season of that epidemic in this country was was in 1844.* Previously to that time, the annual crop of potatoes in the United States amounted to over one hundred million bushels; but, in consequence of the blight, it was reduced in some parts of the country to one-half or even to one-quarter of the ordinary yield.†

In 1845, it showed itself in England, Scotland, and Ireland, and spread with great rapidity. This is the account of it given by Mr. Cooke,‡ one of the highest authorities on that subject:

"It first appeared in the Isle of Wight, in the middle of August; a week afterward it had become general in the south of England, and at the end of a fortnight there were but few sound samples of potatoes in the London market. The course of the disease was this: in the month of July or August the leaves of the vines would be suddenly seen to be marked with black spots. They then began to wither, and give off an

* American Quarterly Journal of Agriculture and Science, January, 1845.

† "Patent-Office Reports, Department of Agriculture," 1856.

‡ "Introduction to the Study of Microscopic Fungi," London, 1870, pp. 144, 146.

offensive odor, and the disease spread so rapidly that the whole vine would be blighted in a few days, and a field, which had before been covered with a luxuriant growth, at the end of a fortnight was merely a scene of desolation, and looked as if it had been struck by a severe frost. If the potatoes were immediately dug out of the ground, many of them were found already partially decayed, or touched with brownish and softened spots."

The disease broke out again in 1854 and 1855, and was destructive in the State of New York, in Rhode Island, Massachusetts, Ohio, Illinois, and at various other points ;* and about 1865, or ten years later, it made its appearance for a third time. I am told by an old and experienced farmer of Washington County, New York, that in 1864 and in 1865 the potato-crop in that region was practically destroyed ; so that often in a twenty-acre field there would not be a single good potato. Potatoes were usually to be had at that place for seventy-five cents per bushel, but in those years they were in some cases sold at eight dollars per bushel, for farmers' consumption.

This destructive malady was at last found to be due to the ravages of a microscopic fungus, called, from its mode of fructification and its injurious effects, the *Peronospora infestans.*

The fungus has a mycelium of fine, cylindrical, ramifying tubes. Its fructifying part consists of filaments which stand up vertically from the mycelium, dividing at the end into four or five branches, and each branch bears upon it several successive swellings, making a kind of sausage-like chain, whence its name of "*Peronospora.*" At the end of each chain there is a complete oval spore, and the spore, when ripe, detaches itself and germinates, to produce again a new mycelium.

When the *Peronospora* is placed in contact with the leaves of a potato vine, its filaments penetrate into and through the epidermic cells, and so reach the intercellular tissue of the leaf and stem ; and there they continue to grow, producing a rapid withering and blight. When the parasite has attained a certain growth, it begins to fructify. Its upright filaments burst through the pores of the leaves, and are crowned with the characteristic chain of spores. Each spore, when ripe, if supplied with moisture, produces six or seven secondary zoospores, armed with long vibrating cilia, and capable of a rapid spontaneous motion. After moving about for a short time, the zoospore becomes quiescent, throws out an elongated filament, and germinates afresh.

It is no doubt in this way that the germ of the parasite reaches the tuber of the potato at the root of the vine. For if sound potatoes be placed in the ground, and the surface of the soil be sprinkled with the spores of *Peronospora*, and then watered from time to time, the potatoes are found to be infested with the disease in about ten days.†

* "Patent-Office Reports, Department of Agriculture," 1856 ; "Massachusetts State Board of Agriculture," 1856.

† Robin, "Traité du Microscope," Paris, 1871, p. 967.

So the fructification of the fungus naturally takes place upon the surface of the leaves of the potato-vine. The spores fall off, are carried by the rain into and through the soil, and so reach the potatoes beneath. Next year, when the infected potato-eyes are planted, germination begins again, the mycelium filaments grow upward through the stem and leaves, and in July or August fructification appears on the exterior as before.

This species affords a good example of the extreme fecundity of the parasitic fungi. It has been estimated that, on the under surface of a potato-leaf, one square line is capable of producing over three thousand spores. Each spore supplies at least six zoospores; so that from one square line we may have nearly twenty thousand reproductive bodies, each capable of originating a new mycelium; and a square inch of surface may yield nearly three million such bodies.

The mycelium filaments can penetrate the cellular tissue of a leaf in twelve hours, and, when established there, may grow and bear fruit in eighteen hours longer, while the spores are perfected and ready to germinate in twenty-four hours after they have been detached and placed in water. This fully explains the rapidity with which the disease is known to spread.

The subject of internal vegetable parasites is of the greater importance, because we now know that they may attack animals as well as plants. The best illustration of these affections is perhaps the disease which, under the name of *pebrine*, has been so destructive to the silk-worm in France. Eight or ten years ago its effects were so serious that, in 1865, the annual production of silk in that country was reduced to less than one-sixth of its former average, and the loss in money-value for that year alone amounted to twenty million dollars.* It was due entirely to the influence of a microscopic vegetation, which destroyed the silk-worm, and was readily communicated to the neighboring broods.

It is plain, therefore, that the study of parasitic diseases, for many years, has been increasing in development and becoming of greater importance in general pathology. From being confined, as at first, to a few cases of local disorder, it has now come to embrace a great variety of morbid affections. It has demonstrated the close connection existing between animal and vegetable pathology, and it has shown that severe and even fatal constitutional disorders of the animal frame may result from the internal growth of microscopic parasites of a vegetable nature. And these facts have been ascertained by patient microscopic investigation, and laborious experiment on the development of eggs and spores, and the phenomena of infection and contagion. It cannot be denied that the results, so far, are genuine.

We now come to a part of the subject which may seem to be less directly connected with medical doctrines; and yet it is one which, if it really have a bearing on pathology, gives to the whole question a character of still greater importance. That is, the true nature of the process of *fermentation*.

* Tyndall, "Fragments of Science," New York, 1872, p. 288.

The more essential phenomena of fermentation have been known from time immemorial. If we add to a solution of sugar, or to any clear vegetable-juice containing sugar, a small portion of yeast, and keep the mixture in a moderately warm place, after a few hours of apparent inactivity, certain remarkable changes take place in it: 1. The liquid becomes uniformly turbid. 2. It is more or less agitated by minute bubbles of gas, which are generated in its interior, rise to the surface, and escape there. 3. The sugar gradually disappears from the solution, and alcohol takes its place. 4. When all the sugar has been thus consumed, the gas-bubbles cease to rise, the liquid again becomes clear and quiescent, its turbid contents being slowly deposited in a whitish layer at the bottom; and, 5. This deposit is found to be itself a layer of yeast, often much greater in quantity than that originally added, and capable of exciting the same kind of fermentation in another saccharine liquid.

Besides this, chemical investigation has shown that the gas evolved is carbonic acid, and that the weight of the sugar which disappears is accounted for, within reasonable limits of accuracy, by that of the carbonic acid and alcohol produced, with a little glycerine and succinic acid formed at the same time. It is therefore a chemical transformation, in which the elements of the sugar are separated from their combination, and re-arranged to form other non-nitrogenous compounds.

But it is a chemical change which will not take place spontaneously. It requires the presence of yeast artificially added, or of a natural ferment, present in the vegetable-juice. The theory of fermentation formerly in vogue was, that the nitrogenous matter in solution in the yeast excited, by its own molecular changes, the decomposition of the sugar; taking by itself no direct part in the chemical phenomena, and neither absorbing nor discharging any of the materials of the solution.

In enumerating these facts I do not always follow the exact chronological order in which they were discovered, nor do I wish to take up your time in alluding to all the details and varieties of fermentation. It will be sufficient for our present purpose to bear in mind simply the main features of the process, namely, the addition of ferment to a saccharine liquid, turbidity of the solution, decomposition of the sugar, appearance of alcohol and carbonic acid, and, finally, reproduction of the ferment.

Two hundred years ago Mr. Anthony Leeuwenhoeck was investigating all sorts of natural objects with his newly-constructed microscopes, consisting each "of a very small double convex glass, let into a socket between two silver plates." He examined the blood-globules, the capillary vessels, the spermatic corpuscles, the structure of wood, of hair, of teeth; and with the same instruments he saw in yeast little globules collected into groups of three or four together.* But he had too many other novelties, all attracting his attention together, to spend much time on any one of them, and he did not learn the nature or spe-

* "Philosophical Transactions," 1681, p. 507.

cific characters of the globules of yeast; he only determined the bare fact of their existence.

But in 1837 the French chemist Cagniard-Latour* examined the yeast-globules with more care. He measured their size, and found them to be at most $\frac{1}{2500}$ of an inch in diameter. He declared that they were of a vegetable nature, and that they multiplied by the process of budding. He called attention to the fact that during the fermentation of beer the ferment increases in quantity, producing at the end of the process six or seven times as much yeast as was introduced at the beginning; and he first broached the idea that "it is probably by some effect of their vegetation that the yeast-globules destroy the equilibrium of the elements of the sugar."

The theory, however, was at that time premature, and it did not meet with general acceptance. The existence of the yeast-plant, so far as then known, was an isolated fact, confined to the single case of fermenting beer. The opposite theory, of the catalytic action of an albuminous liquid, was maintained by Liebig with all the force of his remarkable genius, and was consequently almost universally adopted. The yeast-plant was thought to be an incidental growth in the fermenting fluid, and not to have any direct or important connection with the process itself.

About fifteen years ago a new epoch was inaugurated in the history of fermentation by the brilliant researches of Pasteur. The existence and growth of a fungoid vegetation were now found not to be confined to the single case of beer-yeast, but to be a general fact common to the alcoholic fermentation of beer, wine, and bread, and also to a variety of other kinds, such as the viscous, butyric, and acetic fermentations. The fungus itself was industriously studied in its different genera and species, with their specific modes of growth and reproduction, like those of any other natural family of plants; so that the *Saccharomyces cerevisiæ*, or the yeast-fungus of beer, can now be distinguished from the other species of alcoholic ferments, as well as from the fungi of other kinds of fermentation.

The different view thus introduced is most distinctly expressed by Pasteur himself. "According to the old theory," he says, "fermentation is a process correlative with death, and depends on the decay of albuminous matter; according to the new one, it is correlative with life, that is, the active growth and development of the fungous vegetation. * * The yeast-globules are actual living vegetable cells, capable of producing the transformation of sugar, just as the cells of the mammary gland in a living animal transform the ingredients of the blood into the ingredients of the milk."

The discussions on this subject, which lasted for ten years, took a very wide range, and especially became connected with the kindred topic of "spontaneous generation." The experiments of Pasteur and

* "Annales de Chimie et de Physique," 1838, tome lxviii, p. 216.

others showed that the germs of the yeast-plant may be disseminated by the atmosphere, and that the same precautions which exclude the introduction of germs from without into a fermentable liquid also exclude the process of fermentation itself; so that we can now accept with confidence the double fact—1. That the growth and reproduction of the yeast-fungus will take place only in a fermentable liquid; and, 2. That such a liquid will ferment only when the yeast-fungus is present and in a state of active development.

The revolution in opinion on this point was so complete that, in regard to the alcoholic fermentation at least, its essential results were finally accepted by Liebig himself. In his last treatise on fermentation, published in 1871, he says: * "There no longer remains any doubt as to the nature of the ferment of beer and wine. It is a cryptogamic vegetation, more or less fully developed * * * We may conclude that the albuminous matters of the yeast take part in its action upon the sugar, and it is evident that these albuminous matters acquire their property of exciting fermentation by becoming an actual constituent of the yeast itself."

Consequently, the fermentation of a saccharine liquid is the result of vegetative activity. We add to the liquid a few cells or spores of the yeast-fungus. These grow and multiply, and the turbidity of the liquid is due to their increase and dissemination. They decompose its sugar, appropriate some of its elements, and leave as a result alcohol and carbonic acid. When all the sources of their nourishment are exhausted, fermentation stops, and the liquid becomes clear, the yeast-cells subsiding to the bottom. But the ferment has in the mean time been reproduced, like so much grain which has been sown, raised, and harvested; and a little of the deposit left at the bottom of the vessel, if introduced into another saccharine liquid, will in turn reproduce the process of fermentation.

It is impossible not to perceive a certain analogy between the general phenomena of fermentation and those of contagious and infectious diseases. The period of incubation which intervenes between the exposure to a contagion and the appearance of the malady—the regular course of the symptoms—their natural termination within a definite time, and the evident reproduction of the contagious element—all these facts were so many points of resemblance, which could not escape the attention of medical observers. The analogy, indeed, has long been recognized in our nomenclature; and the term *zymotic diseases* cannot mean anything else than diseases depending upon some cause which acts after the manner of a ferment. But this name was adopted only as a matter of convenience, and was understood altogether in a symbolical sense. Of late we have begun to suspect that after all it may be simply the expression of a literal fact.

A similar order of discoveries has recently been made with regard to

* "Annales de Chimie et de Physique," 1871, tome xxiii, pp. 9, 10.

putrefaction. This has a more immediate connection with pathology than fermentation, because it is a change which takes place in animal substances, while fermentation, at least in its simpler forms, relates mainly to products of a vegetable origin.

Putrefaction was formerly regarded as the natural and inevitable decomposition of dead animal matter when exposed to the oxygen of the atmospheric air. But in reality something else is necessary. In every putrefying liquid there are a growth and development of minute living organisms. If we take a clear solution of any nitrogenized animal or vegetable matter and expose it to the air at a moderate temperature, after a short time it becomes turbid. This turbidity is the first evidence of commencing putrefaction, and it is exactly analogous to the turbidity of a saccharine liquid which is beginning to ferment. Microscopic examination shows that it is due to the presence of innumerable *Bacterium*-cells, $\frac{1}{8000}$ of an inch long, by $\frac{1}{40000}$ of an inch wide, moving in every direction, and multiplying by a rapid process of subdivision. As long as putrefaction goes on, so long the *Bacteria* multiply. When it comes to an end the liquid becomes clear, and there is a quiescent layer of *Bacteria* deposited upon the bottom. The least particle of this layer added to another albuminous liquid will excite putrefaction in it, and will produce a new development of *Bacterium*-cells, the quantity of which is limited only by that of the albuminous matter which serves for their nourishment and growth.

Now, *Bacteria* are the smallest and most obscure of living things Their minute size alone is a sufficient obstacle, with our present microscopes, to their complete and satisfactory study in all particulars. Nevertheless, some important facts have been established with regard to them. In the first place, they are undoubtedly vegetable in their nature, and consist of cells which multiply by division, not by budding. They require for their growth a temperature between the limits of freezing and boiling water. They consist of a protoplasmic matter, surrounded by an envelope of vegetable cellulose. They live upon nitrogenized and carbonaceous organic matters in solution, and, like other colorless plants, absorb oxygen and exhale carbonic acid. They present a variety of genera and species, which may be distinguished from each other with some approach to accuracy; and, of these, *Bacterium termo* is the most constant and indispensable inhabitant of putrefying infusions.

As to the true relations between bacteria and putrefaction, almost the same course of inquiry has been followed as in the case of the yeast-fungus and fermentation. At first regarded simply as an incidental accompaniment of the process, they are now considered as its essential and immediate cause. This view is distinctly stated by Dr. Ferdinand Cohn, to whom we owe more definite information on the natural history and microscopic characters of *Bacteria* than to any other observer. Dr. Cohn is a professed scientific and experimental botanist, and director of the Institute of Vegetable Physiology at Breslau. He was the first to

establish, twenty years ago,* the vegetable nature and structural relations of *Bacteria*, and he has recently contributed largely to our knowledge of their classification and general physiology.† According to him the putrefaction of nitrogenous organic matters is neither a spontaneous *post-mortem* decomposition, nor is it a simple oxidation under the influence of the atmosphere. "It is rather a chemical process caused by the action of *Bacterium termo.* Just as sugar is never converted spontaneously into alcohol and carbonic acid, and is brought into fermentation only by the yeast-fungus, so nitrogenous organic matters never putrefy of themselves, but only by means of the vital activity and multiplication of *Bacteria.* * * * We may therefore," he says, "apply Pasteur's doctrine also to the decomposition of animal matters, and may adopt as true the seeming paradox that *putrefaction is an incidental phenomenon, not of death, but of vitality.*"

The proof that living *Bacteria* are the cause of putrefaction, and not merely its accompaniment, is that a putrescible liquid which has been sufficiently boiled and received in a super-heated glass vessel may be kept in contact with the atmosphere indefinitely without putrefaction, provided the access of *Bacteria* be prevented by a plug of cotton-wool. But, if the minutest portion of any liquid already infected with *Bacteria* be added, putrefaction at once begins. Dr. Burdon-Sanderson, by a series of very important experiments in 1871,‡ has established the fact, which is also confirmed by the researches of Cohn,§ that contamination by the germs of *Bacteria* takes place, as a general rule, not directly from the atmosphere, but by means of water and unclean moist surfaces; while, on the other hand, the germs of the mold-fungi, like penicilium and mucor, are more or less constantly present in the air, and so readily gain access to organic substances, even in a dry atmosphere. Consequently, such substances, if properly protected against *Bacteria*, do not putrefy, but, on the other hand, may become covered with a mold-fungus. Dr. Sanderson even cut out the muscular tissue of the thigh of a recently killed Guinea-pig, and hung it up under a bell-glass, using for this purpose a knife and hooks which had just been subjected to the flame of a Bunsen burner, but taking no other precautions; and for thirty-one days, though the exposed tissues were overgrown with penicilium, there was no development of *Bacteria*, and no evidence of putrefaction.

The natural history of *Bacteria* is especially connected with the question of spontaneous generation, because they are the only class of organisms now remaining in which reproduction by spores has not yet been discovered, and because they appear so promptly and abundantly in all putrescible liquids under ordinary exposures.

Whatever may be the difference of opinion, therefore, with regard to

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* "Nova Acta Academiæ Carolo-Leopoldinæ," lib. xxiv, p. 1.

† "Beiträge zur Biologie der Pflanzen," 1872, No. ii, p. 127.

‡ "Thirteenth Report of the Medical Officer of the Privy Council," London, 1871.

§ "Beiträge zur Biologie der Pflanzen," No. ii, p. 189.

the possibility of spontaneous generation within limited and exceptional conditions, there is hardly a doubt remaining that as a rule, in the regular operations of nature, the *Bacteria* or their germs are, in point of fact, conveyed from one putrefying substance to another, and that putrefaction is a process excited by contagion, and accomplished only by the growth and nutrition of *Bacteria.*

It was an important discovery, when it was found, ten years ago, that *Bacteria* might be developed in the interior of the living animal organism. In 1863 and 1864, Davaine* showed that in the disease of sheep, known in France as "*charbon*" or "*sang de rate*," and called by the Germans "*milzbrand*," the blood of the affected animal, during life, contained *Bacteria.* He showed that the disease might be communicated by inoculation to other animals, always with a fatal result, and always with the development of *Bacteria* in the blood previous to death. He afterward† extended the same observation to cases of malignant pustule, which he declared to be one form of the "*sang de rate*" disease.

In 1868 Vulpian‡ found that a fatal disorder might be produced in frogs by the administration of cyclamine; that the malady was accompanied by the development of *Bacteria* in the blood, and that inoculation of this blood reproduced the disease in other healthy animals of the same species.

About the same time, Professors Coze and Feltz,§ formerly of the University of Strasbourg, had been making researches in a similar direction. They ejected putrescent liquids into the veins or subcutaneous tissue in dogs and rabbits, producing in this way a fatal artificial *septicœmia;* and they found that *Bacteria* were developed in the blood of the animal simultaneously with the appearance of the febrile condition. But the effect produced did not stop there. The blood of such an animal, though not itself putrid, had become infectious, and would excite *septicœmia* in another animal by inoculation. A still further remarkable result was obtained from these experiments: "By reproducing in this manner," the authors say, "several successive inoculations, it becomes evident that the infectious element is at last more active than the putrescent matters themselves. Injection of putrescent liquids is not so rapidly fatal as inoculation of the blood of an animal already infected."

These facts have been confirmed by the observations of Davaine and Vulpian, which show the extraordinary activity of infectious blood, even at a high degree of dilution. Davaine|| found that putrefied bullock's blood, injected into the subcutaneous tissue of the rabbit, was rarely fatal in doses of less than $\frac{1}{100}$ of a drop, and never so in less than $\frac{1}{2000}$. But a series of twenty-five successive inoculations showed that *septicœmia*, once established, could be transmitted to the healthy rabbit by a

* "Comptes Rendus de l'Académie des Sciences," tomes lvi, lix.

† "Comptes Rendus," 1865, tome lx, p. 1297.

‡ "Archives de physiologie normale et pathologique," 1868, p. 466.

§ "Recherches cliniques et expérimentales sur les maladies infectieuses," Paris, 1872.

|| "Bulletin de l'Académie de Médecine," Septembre 17, 1872.

dose of infectious blood so diluted that it represented only one-trillionth part of a drop. Vulpian* injected a rabbit with infectious serum, and produced death in twenty hours. A second rabbit was inoculated with the blood of the first, diluted to $\frac{1}{50}$, and died in twenty-four hours. A third rabbit was inoculated with the blood of the second, diluted to $\frac{1}{1000}$, and died in twenty-three hours. A fourth animal, inoculated with the blood of the third, diluted to $\frac{1}{1000000}$, died in fifty-two hours; while the fifth, inoculated with a dilution of $\frac{1}{1000000000}$, became ill, but finally recovered.

In cases of *septicœmia*, therefore, the *Bacteria* really multiply in the circulation during life; and the small quantity of infectious blood necessary to produce the disease is explained by their singular activity of reproduction.

These experiments certainly bring the study of morbid contagion into very close relationship with that of putrefaction and fermentation; and there is no doubt that the analogies between them become more distinct and suggestive at every step of the investigation. It only remains to show that the same results will apply to diseases of more regular type and more familiar occurrence.

If we were to choose any single morbid affection as a fair representative of the whole class of contagious disorders, I suppose small-pox would be the one selected. Its virulence, the certainty of its communication, the abundance of infectious matter generated, the regularity of its symptoms, and the definite periods of its incubation and development, all make it, so to speak, a kind of exponent of the essential qualities of infectious disease. Besides this, its singular relations to vaccine give it a peculiar interest; and the vaccine affection also, though milder in its symptoms, is hardly less marked as a contagion than small-pox itself. Conclusions derived from experiments with either must be of great value in regard to the study of contagion as a whole.

The first definite experiments in regard to the contagion of vaccine we owe, I think, to Chauveau.† He endeavored to ascertain whether the contagious principle of vaccine lymph is in its liquid or in its solid portions. For this purpose he treated vaccine lymph by the process of diffusion. The result showed that the contagious property of the lymph does not reside in its liquid part, but in its solid corpuscles and granulations. The liquid withdrawn by diffusion, though always found to contain abundance of albuminous matter in solution, failed when used for vaccination; while that containing the solid granules possessed its normal activity and succeeded as fully as the fresh lymph. The results of these diffusion experiments were confirmed by those of Dr. Burdon-Sanderson,‡ performed subsequently.

Chauveau also adopted a second plan for investigating the same point,

* Gazette Médicale de Paris, 1873, No. 3, p. 30.

† "Comptes Rendus de l'Académie des Sciences," 1868, tome lxvi, p. 289.

‡ "Twelfth Report of the Medical Officer of the Privy Council," London, 1870, pp. 233, 235.

namely, that by dilution. The significance of this test depends on the following consideration: If the real vaccine virus be a fluid, it is of course uniformly distributed through all parts of the lymph; and if this lymph be diluted to any extent, the fluid virus will still be equally disseminated throughout the whole. When the dilution becomes so great as to extinguish the activity of the virus, this activity ought to diminish and disappear at the same time uniformly through all parts of the liquid. On the other hand, if the contagious principle reside in the solid particles, each one of which is capable of reproducing its kind, these particles will only be separated from each other by the dilution, and made less likely to be taken up in the drop used for vaccination. But, if one of them should be so taken up, it would still produce its full effect. In this case, the number of successful vaccinations would diminish in proportion to the dilution, and the number of failures would increase. But every vaccination which failed would fail completely, and every one which succeeded would produce a normal result.

Chauveau's experiments showed that the latter supposition was correct. Vaccine lymph might be diluted with from two to eighteen times its weight of water without sensibly losing in efficacy; and in one case the experimenter obtained a single pustule from a number of vaccinations made with lymph diluted to $\frac{1}{150}$. He obtained, however, the most remarkable results with the lymph of sheep-pox, upon which he experimented largely.* He inoculated the same animal, by twenty-one punctures, with pock-lymph diluted to $\frac{1}{500}$; and of these twenty-one inoculations eight failed, while thirteen gave origin to full-sized pustules. He then diluted the pock-lymph at once to $\frac{1}{10000}$; and with this diluted lymph, out of twenty inoculations he obtained only a single pustule, but that pustule presented its normal features, and went through the usual stages of development.

The active properties of the lymph of vaccine and variola, therefore, do not reside in its liquid ingredients, but in its solid corpuscles. These corpuscles, which were already observed by Chauveau and Burdon-Sanderson, have been recently examined and described with great care by Dr. Cohn.† This observer adopted every precaution against the introduction of foreign elements into the lymph. Some children with healthy vaccine vesicles were brought to the Botanical Institute, the vesicles opened with a new, unused lancet, the lymph taken up by aspiration in a recently-heated capillary glass tube, dropped upon a microscope-slide, and fitted with a glass cover, both the slide and cover having just been thoroughly cleansed with ammonia and boiling water. The edges of the cover were then lacquered down, to exclude the air, and the lymph-corpuscles examined at successive intervals of time.

According to Dr. Cohn's observations, these corpuscles are single cells

* "Comptes Rendus," 1868, tome lxvii, p. 749.

† "Organismen in der Pockenlymphe." Archiv fur pathologische Anatomie und Physiologie, 1872, pp. 55, 229.

of a spherical form, not more than $\frac{1}{25000}$ of an inch in diameter. They belong to the genus *Micrococcus*, and those of the vaccine lymph are designated by the name of *Micrococcus vaccinæ*. They increase in numbers if kept at the temperature of the living body, forming chains and groups of associated articulations. Dr. Cohn finds similar bodies in the fluid of small-pox vesicles, identical in size and appearance with those of the vaccine lymph. "We must, therefore," he says, "for the present regard the pock-lymph corpuscles as living and independent organisms, belonging to the smallest and simplest of all living things, which multiply, without formation of mycelium, by cell-division alone, and perhaps also by the production of resting spores."

Finally, another kind of micrococcus has been described by Dr. Oertel,* of Vienna, and by Prof. Ebert,† of Zürich, as constantly present in cases of diphtheria; and both observers have found that its inoculation in different parts of the body in healthy animals produces a diphtheritic malady, having its starting-point at the place of inoculation.

The contributions to medical literature on this subject have increased of late with unusual rapidity. Since the beginning of 1870 more than two hundred distinct publications have made their appearance, either in the medical journals, or as separate volumes, on septicæmia and diphtheria, on micrococcus and bacteria, the ferment-corpuscles, fermentation and putrefaction, their relation to contagion and infection, and kindred topics. Many of these essays are extremely important, others of more or less doubtful value. I have not attempted to notice them all, but only those which seem to have really established some new facts relating to the origin and propagation of disease. Should the discoveries of the next ten years continue to lead in the direction now indicated, it will illustrate more fully than ever the intimate relation which exists between all the branches of medicine and natural science; for it will show how large a part of human pathology is connected with the general physiology of vegetative life.

In connection with this subject a considerable degree of interest attaches to the ingenious experiments of Professor Tyndall on the dust-particles suspended in the atmosphere. The fact that the atmosphere is almost never free from floating molecules, diffused in greater or less abundance by the air-currents, has for a long time attracted attention; and it is a common observation that these dust-particles, even when invisible by diffused daylight, may at once be rendered evident by admitting a sunbeam into a darkened apartment. The minute particles then reflect the light, and become distinctly visible in the track of the beam by contrast with the surrounding non-illuminated space. Professor Tyndall, by passing the electric beam through a closed glass tube, has shown that the atmospheric air, however transparent it may appear to ordinary vision, is never so free from suspended particles that it will not

* "Deutsches Archiv für klinische Medicin," 1871, B. viii, p. 242.

† "Zur Kentniss der bacteritischen Mykosen," Leipzig, 1872.

betray their presence, under such circumstances, by a luminous track passing lengthwise through the tube. In following out these investigations, he arrived at two rather unexpected and somewhat important results.

The first was that the solid corpuscles in suspension in the atmosphere are to a very great extent of *organic origin.* As the dust which settles upon our shelves and moldings, when collected and examined, was known to be largely composed of mineral particles, it was naturally thought that the floating impurities of the air were probably of a similar character. But when Professor Tyndall allowed the illuminated electric beam to pass directly over the flame of a spirit-lamp, he found that a perfectly dark space was cut out of the beam—wreaths of darkness rising upward from the flame and taking the place, at that point, of the luminous particles. A hydrogen flame, a red-hot poker, or a bundle of incandescent platinum wires, placed in a similar position, produced the same effect. That is, the floating molecules of the air, which have the power of dispersing the light of the electric beam, instead of being rendered incandescent and more luminous than before by a high temperature, are destroyed by it and resolved into transparent vapors. They are therefore combustible and organic.

This fact is of great importance, because it gives us our first definite knowledge with regard to the nature of the greater part of the atmospheric dust. If this be really the channel by which germs of disease are disseminated in the form of distinct corpuscles, we shall never be fully satisfied until we have been able to examine and recognize them, so as to place the fact beyond a doubt. But thus far it has been found exceedingly difficult to capture and place under the microscope the minute ingredients of the atmospheric impurities. This has, it is true, been accomplished for a very few of the simpler and well-known fungus germs; but as for the larger portion of the floating particles which a sunbeam brings into view, our knowledge has heretofore been limited to the mere fact of their existence. It is therefore a great step to learn that, whatever may be their remaining characters, they are at all events of organic origin. The minute size of these bodies, and especially their lightness, no doubt explain fully the persistence with which they are raised and disseminated by the gentlest air-currents, while the heavier particles of a mineral nature are more readily deposited in the form of dust upon all inclined and horizontal surfaces.

The second fact brought out by the observations of Professor Tyndall is the extreme difficulty of excluding from the air all of its finer dust-particles, so as to obtain it absolutely free from suspended matter. The electric beam, passing through the glass tube before spoken of, was used by the experimenter as a test for the presence of solid impurities in the air contained in the tube. As the beam is, of course, invisible by itself, and becomes perceptible to the eye only by meeting with bodies capable of reflecting its light, any luminosity in its track through the tube would

indicate the existence of floating particles in the contained air. It was found by this test that, contrary to expectation, air which had been passed in succession through tubes containing fragments of glass wetted with concentrated sulphuric acid and with a solution of caustic potash immediately before its admission to the tube still contained similar impurities. Even when it had been allowed to bubble through the liquid sulphuric acid and caustic potash, the electric beam still revealed the presence of suspended matter. Either the contact of these liquids could not be made sufficiently complete with all parts of the air passing through them, or for some other reason they failed to purify it entirely of its organic ingredients.

But a burning temperature succeeded in accomplishing the object. A platinum tube, containing a roll of platinum gauze, was placed in a small gas-furnace, and heated to incandescence. The air was slowly drawn through this apparatus, and then, when admitted into the glass experimental tube, was found to be absolutely free from suspended material. The electric beam passed through it, from end to end, without exhibiting any luminosity; the interior of the tube being perfectly dark, while outside of it the track of the beam was lighted up by floating dust-particles, as before. A tube filled with air in this condition was said by Professor Tyndall to be *optically empty;* that is, it contained only the transparent gases of the atmosphere without any admixture of corpuscles capable of reflecting light.

The air may also be freed from its suspended impurities by filtration through cotton-wool. A quantity of this substance was packed rather tightly in a glass tube, so as to form a thick, porous plug. The air, drawn through this tube into the experimental receiver, showed itself to be non-luminous, and consequently pure. This property of cotton-wool has been often utilized in experiments on the necessary conditions of organic development, and it is found that air thus thoroughly filtered does not carry with it any germs capable of producing infusorial or vegetative life.

Finally, Professor Tyndall also demonstrated that air, which has once passed through the deeper portion of the respiratory passages, has undergone a similar filtration. If the expired breath be made to traverse a luminous electric beam, it at first produces upon it no visible effect. But toward the end of the expiration it makes itself evident by a diminution in the amount of dispersed light, and at last extinguishes completely the luminosity of the beam, cutting out at the point of contact a perfectly dark space. Precisely by what mechanism this filtration is accomplished it is not easy to say, since the smallest of the pulmonary passages in the human lung have a diameter of not less than one-fifth of a millimeter; but there can be little doubt, in point of fact, that by the time the air reaches the ultimate divisions of the respiratory cavities, it is thoroughly freed from the ordinary suspended matter which it contained on entering the trachea.

ON LATER VIEWS OF THE CONNECTION OF ELECTRICITY AND MAGNETISM.

REVIEW OF MATHEMATICAL THEORIES.

By Professor Helmholz.

[From the London Academy.]

The problem of determining the primary causes of the so-called electro-magnetic and electro-dynamic phenomena is connected intrinsically with some of the most important theoretical questions of natural philosophy regarding the general character of force and the essential attributes to be ascribed to the medium which fills space. The subject, therefore, has attracted the attention of natural philosophers and mathematicians since the time of Oersted's first discovery regarding the deviation of a magnetic needle by a galvanic current, in 1820, till the present moment; and this attention has grown even the more intense and concentrated the more our knowledge of the experimental facts approached to completeness. The force of gravitation, Newton's grand conception, has been hitherto the model for nearly all the scientific hypotheses by which philosophers have striven to connect and to explain the various kinds of physical and chemical phenomena. Hypotheses of this kind, based on the assumption of forces acting between two material points along the straight line of their junction, either attracting or repelling, the intensity of which is independent of time and velocity, but dependent on the distance of the two points, have been applied with great success, not only to the effects of celestial and terrestrial gravity, but also to those of elasticity in rigid, fluid, and gaseous bodies, including the phenomena of sound and light. In the theory of heat and chemical actions, it appears highly probable that we have to do with forces of the same kind, although of a much more limited sphere of activity. In consequence of the extreme complexity of causes and conditions, only very small parts of these branches of science have been worked out so far that the connection between actual phenomena and elementary forces can be traced the whole way and deduced by mathematical analysis. The nearest analogy with the laws of gravitation we find in the phenomena of electricity and magnetism as long as these agents are in a state of repose and equilibrium. We find the same law of action at a distance, and the inferences derived from this law are even more open to controlling experimental measurements of the highest degree of precision than those of gravitation, or of the molecular forces, which keep up the motion of heat, produce chemical combinations, and are the alternate cause of elasticity. The very existence of the electro-static and magnetic forces must have increased a good deal the tendency of natural philosophers to generalize this kind of hypothesis, which answered so well to the requirements of

science, and to consider the attributes of these forces enumerated above as the general and necessary attributes of all ultimate forces of nature.

In order to distinguish the forces of this description by a short name, I may be allowed to call them forces of the first class. Forces the intensity of which depends either on time or on velocity may be disposed of in a second class.

Are there really alternate and elementary forces, which are to be reckoned into this second class, which cannot be reduced into an aggregate of forces of the first class, and do not bend under that great generalization, like the majority of other physical and chemical forces? This is, evidently, a question of the highest theoretical interest, and the problem of electro-dynamics turns out so important, because the so-called electro-dynamic forces, acting between two electric currents, or between one such current and a magnet, seemed really to afford an example of the second class.

First among them we have the discovery by Oersted of the forces moving ponderable matter, (*pondero-motor* forces, according to Prof. C. Neumann's nomenclature,) and the laws of their action were brought into a relatively simple, accurate, and comprehensive formula by Ampère. These forces are completely latent as long as electricity is in a state of rest; they become active when electricity begins to flow through conducting bodies. This appears as a first fundamental difference between electro-dynamic forces and those of the first class, a general characteristic of which is, that their action is not at all altered by any motion of the points between which they act. Secondly, the electro-magnetic force of a galvanic wire carries the pole of a magnet round the wire without end and without ever leading it to a place of equilibrium and rest. All the forces of the first class, on the contrary, tend to carry the bodies which they move to a certain final resting-place. This relation, moreover, is reciprocal; for just as a magnetic pole is carried around an electric current, a galvanic wire can be carried around a magnet or around a coil of wire, through which an electric current passes.

A second class of electro-dynamic phenomena are the induced currents discovered by Faraday in 1831. In these cases, the electro-dynamic forces do not act on ponderable matter, but they act as *electro-motor* forces on electricity itself. They drive the opposite electric fluids of a wire into opposite directions, either when another wire carrying an electric current is in motion relatively to the first wire, or when the intensity of the current in the second wire is altered. Instead of the second wire, a magnet may be substituted. It produces an induced electro-motoric force either when it is moved or when the intensity of its magnetism is altered. For all these electro-dynamic actions, a magnet may be considered always as a system of electric currents, flowing circularly around the magnetic axis of every magnetized particle.

These electro-motor forces, induced by electro-dynamic action, show the same character as the pondero-motor forces before mentioned. They depend on motion, and the lines along which they act are closed lines without end; for a magnet, losing its magnetism, induces electro-motor forces in circular directions all around its axis.

In spite of this fundamental difference, it has been proved by the experiments of Mr. J. Prescott Joule and by the general theoretical deductions of Sir W. Thomson and the author of this article, that all the known effects of electro-dynamic action are subject to the great principle of conservation of energy, although a theoretical deduction of this universal principle of nature can be given only for forces of the first class, which are independent of motion, and which tend always to a final positionof equilibrium. It can be proved that when an electric currrent, by moving a magnet, does mechanical work, the current induced by the motion of the magnet alters the relation between the chemical processes going on in the battery and the heat evolved in the galvanic circuit, so that a part of the chemical forces is not spent in the production of heat, but used for the mechanical work of the electro-dynamic forces.

There are two principal questions which have been discussed: the one a question of fact; the other a question of theory.

The first is this: hitherto we knew with some degree of accuracy the electro-dynamic actions of closed galvanic currents only, viz, of currents which circulate along a closed line or a system of closed lines, and have no end, where electricity would be obliged to stop and to accumulate. The investigations of Ampère, Gauss, Neumann, (senior,) Kirchoff, W. Thomson, &c., have led to a highly-developed mathematical theory of closed currents, which enables us to calculate their electro-dynamic effects for circuits of any length and form, and which has been compared with actual experimental measurements of the highest degree of precision.

But there exist also currents with ends, as for instance those produced by the discharge of a Leyden battery in the wire which connects the tin-foil coatings of the glass jars. These coatings are the ends of the conducting wire, and they are separated by the insulating glass of the jars. We know that the wire produces electro-dynamic effects during the discharge, like a wire closing together the ends of a galvanic battery, and that the currents in such a wire go to and fro, oscillating between the two tin-foil coatings; but we do not yet know experimentally how far these electro-dynamic actions are modified at the place where the conducting circuit is interrupted by the insulating glass. This question may be of little practical importance, because the actions in question cannot but be very feeble, and it will require great experimental skill to make them visible. On the other hand, in order to define the ultimate causes of electro-dynamic actions, it is necessary to know with certainty the part which every linear element of a current contributes to its general effect, and the linear elements even of a closed circuit are not closed lines, but lines with two ends.

Ampère has derived his well-known law of the attracting or repelling force between two linear elements of electric currents, not, however, without introducing into his reasoning a hypothesis. He assumed, namely, that between every pair of such elements there acts only one force, not a couple of forces, and that the direction of this force is the straight line joining the center of the elements.

Another elementary law was derived from the phenomena of induced currents at first by Gauss, as early as 1835, but not published, and afterward by Prof. F. E. Neumann, (senior,) of Königsberg, in 1845. The mathematical expression of this law was based on the value of the mechanical work which could be done by Ampère's forces, or, as it was called in analogy with the nomenclature applied by Green and Gauss to magnetic and electro-static forces, on the value of the electro-dynamic potential of two currents. This value again was determined completely only for closed circuits, but its mathematical expression led to a value of the same quantity also for linear elements, which is much less complicated than that of Ampère's forces. To calculate it, take the product, 1, of the intensities of the two currents; 2, of the length of both the linear elements; 3, of the cosine of the angle between the directions of the latter, and divide by their distance.

Taken negatively, this potential expresses the potential energy of the pondero motoric forces which is spent when two currents move without altering their intensity, and the forces can be calculated from the value of this energy by well-known methods. Taken positively, the same potential gives the value of the energy, which is equivalent to the existing motion of electricity, and which is spent in induced currents if the intensity of the currents or their position in space is altered. In this way this whole chapter of physics, containing the greatest variety of new and surprising phenomena, has been brought under one most simple law.

As has been said already, the value of the electro-dynamic potential is completely determined for closed circuits, but not for linear elements. To the latter, certain arbitrary functions may be added without altering the potential of closed circuits. Neumann had already remarked this ambiguity. In my first paper I have treated this question, and have striven to find out such consequences of the theory as might lead to an experimental decision of the problematical point. I limited the arbitrariness of the unknown function by the assumption that the law according to which the unknown part of the potential depends on distance is the same as for the known part. Then the whole uncertainty is reduced to the value of one unknown constant, which plays in the theory of electricity nearly the same part as the second constant of elasticity in the theory of elastic solids. I was able to decide one important point at least, namely, that this new constant cannot have a negative value without producing an unstable equilibrium of electricity in conducting bodies. Under such an assumption

certain motions of electricity, as, for instance, radial oscillations in a conducting sphere, ought to grow without end in intensity and to produce an infinite quantity of motion and of heat, which, of course, must be regarded as impossible. This inference was of some importance for our choice between the different theories of electro-dynamics, because it showed that the laws of induced currents derived from the hypothesis of W. Weber, and in the same way those derived from the different hypothesis which Prof. C. Neumann, jr., has proposed, are inadmissible, leading, as they do, to unstable equilibrium of electricity. I do not think that my objections have been invalidated by the arguments brought against them by my opponents, but this I must leave to the judgment of my mathematical readers.

I may omit here, perhaps, another point of discussion. Mr. C. Neumann believed that the law of the forces derived from the value of the potential led to inferences opposed to the results of experiment in those cases where one part of the conducting wire slides along the surface of another part of the same circuit. I have striven to prove that there is no contradiction between the law of the potential, rightly interpreted, and the observed facts.

The potential theory, when applied to the calculation of the pondero-motoric forces, produced by and acting on unclosed circuits, gives not only forces acting between two linear elements of electric currents, according to the law of Ampère, but also other forces acting between the end of the current and a linear element of another, and forces acting between two ends. At the extremities of an open stream-line, quantities of free electricity are either appearing or vanishing. We may say, therefore, that those forces are acting between electricity *in statu nascendi* and streaming electricity.

It was not difficult to prove that the law of the electro-dynamic potential was in accordance with the principle of conservation of energy, even for currents with open ends. It was to be questioned if the same is the case for the original law of Ampère. This question has been investigated by Mr. Neumann, jr. He bases his reasoning on the supposition that forces, one of which acts between every pair of linear elements of currents, are the only pondero-motoric forces existing. Besides, he supposes that the forces of superimposed currents are simply superimposed themselves, and that the principle of conservation of energy is valid. He concludes from a very clever and skillful analysis that these assumptions are sufficient to determine all the questionable points. But the law of induction produced by change of intensity, which results from his analysis, corresponds to an unstable equilibrium of electricity, and to a negative value of the constant, introduced by myself. I infer, therefore, from the results arrived at by Prof. C. Neumann that his hypothesis is inadmissible, and that there must exist, in reality, other pondero-motoric forces at the ends of currents besides those of Ampère. I think that the theory based on the existence of an

electro dynamic potential is the only theory hitherto known which gives a complete and unobjectionable expression of all the different classes of electro-dynamic phenomena. It is recommended, besides, by the extreme simplicity of its fundamental law.

Now we come to the second fundamental question. It must not be forgotten that the mathematical laws hitherto spoken of give not an explanation of the ultimate *vera causa* of electro-dynamic effects, but only a comprehensive and precise determination of their quantitative value. They perform as much for the knowledge of these actions as the laws of Kepler did for astronomy. But the work of Newton has also to be done for this branch of science.

In order to find the real elementary causes of electro-dynamic effects, two different ways have been followed, the one by Gauss, the other by Faraday.

Gauss thought that the distinguishing peculiarities of electro dynamic forces might depend on the time which they required to reach distant points of space. Among the papers published after his death, in the collection of his works, there are some very remarkable attempts of this kind. One of these papers, written in 1834, (Gauss, Werke, bd. v, p. 617,) contains the nucleus of a theory similar to that published some time later by his friend and collague, Prof. W. Weber, and perhaps even less objectionable. But Gauss did not publish anything about this subject. "Nil actum reputans, si quid superesset agendum," as he says himself.

Among the theories of this kind which have received the most elaborate development, and have met for a long time with the almost general assent of continental philosophers at least, was the theory of Prof. W. Weber, of Göttingen. It has played a prominent part as the theoretical basis of the highly important experimental measurements by which Professor Weber determined the fundamental natural constants of this branch of science. According to this hypothesis, every quantum of electricity exerts upon every other quantum a force the value of which not only depends on the actual distance of the two electric quanta, but also on the velocity with which this distance is changed and on the acceleration of this velocity.

Sir W. Thomson and Prof. P. G. Tait were the first who pronounced this hypothesis of Weber to be contradictory to the principle of conservation of energy, without specifying their objection. I was led to the same inference by independent investigations, as mentioned above.

Besides this, the late Professor Riemann and Prof. C. Neumann, jr., have tried to develop the idea of Gauss. The latter has given a relatively simple mathematical form to the assumptions necessary for this end. These assumptions, interpreted physically, are rather startling, and, besides, this hypothesis leads to the same contradiction of the law of conservation of energy as the law of Weber. Hitherto, therefore, the theoretical attempts of this class have not been very successful.

Another way has been entered upon by Faraday. He objected to all forces acting into distance without intermediate links of connection, and he endeavored to show that electric forces spread out by contiguous modifications of the medium, filling the space between the electrified bodies. He succeeded, at least, in proving that electric as well as magnetic action into distance is not independent of the medium through which it is propagated; and the phenomena of diamagnetism, discovered by him, go on in such a way as if diamagnetic bodies had even less magnetic polarity than the ether of a vacuum. Faraday concluded from his researches that the molecules of electric insulators (dielectric media) are influenced in the same way by electric forces as the molecules of magnetizable bodies are influenced by magnetism; that a separation of the two electricities, or, as he calls it, *dielectric polarization*, goes on, in the first case, as there is a separation of the magnetic fluids, or *magnetic polarization* in the second. Prof. C. Maxwell has brought these conceptions of Faraday into a precise mathematical form. He dispenses completely with forces acting at a distance, and assumes actions going on in every elementary volume of ether of the same direction and of the same kind as the electro-magnetic actions between magnets and galvanic conductors of common size and distance. According to his opinion, every change of magnetic polarization in an elementary volume of ether produces in the same element an electric force of a circular direction around that of the magnetic momentum, and every change of dielectric polarization, which is equivalent to a flow of electricity through the molecule, produces magnetic force, acting in a circular direction through the same molecule. In the interior of electric conductors he supposes that dielectric polarization is continually fading away by a certain imperfect elasticity of the ether. These assumptions give, indeed, a sufficient basis for the development of a complete mathematical theory of electro-static, electro-dynamic, and magnetic phenomena. It is in perfect accordance with the results of experiments hitherto performed, and with the laws derived from the existence of an electro-dynamic potential, at least for moderate distances, through which light is propagated in a time the duration of which may be neglected. But the theory of Maxwell also indicates that electro-dynamic action is not propagated instantaneously into distance, and it is highly remarkable that the velocity of the propagation, calculated from experimental data which were obtained at first by W. Weber, coincides almost perfectly with the velocity of light. This coincidence had been remarked before by Kirchoff for the propagation of electric currents in conductors of infinitely small resistance. An ether, indeed, with the faculty of electric and magnetic polarization, which Professor Maxwell ascribes to the ether of insulating media, can propagate transverse electric and magnetic oscillations with the velocity of light. Magnetic and electric oscillations must be combined in this case always in such a way that their directions are perpendicular to each other and to the direction of propagation. The old undulatory

theory of light, in which the mechanical attributes of a rigid elastic solid are ascribed to the ether, is beset with many theoretical difficulties. It appears that the new electro-magnetic theory of light answers better in some cases, as, for instance, in the theory of reflection and refraction; whether it does so everywhere must be decided by its further elaboration. This natural and unsought-for connection of the new electro-magnetic theory with the theory of light is, indeed, an important success, which gives rise to the greatest hopes for the future.

In his former papers, Professor Maxwell has already shown that the same kind of influence which, according to his electro-dynamic theory, neighboring elementary volumes of ether have upon each other, can be imitated by a mechanism containing a system of rotatory elastic spheres, every one of which acts on its neighbors by means of a system of friction-balls interposed between them. Such a mechanism may appear rather too complicated for the structure of the ether; nevertheless, it is a result of great general importance that actions the laws of which are congruent with those of electro-dynamic phenomena can be produced by the play of common mechanical forces.

Recently Prof. Clerk Maxwell has given, in his treatise, (p. 111, ch. 6,) a more general and abstract demonstration of the same result, derived from Lagrange's (or Hamilton's) general principles of mechanics. He takes for that end the electro-dynamic potential as expressing the *vis viva* of all the known and unknown motions which are connected necessarily with the motion of electricity in a conductor. Without any special assumption about the nature of these motions, the laws of pondero-motoric and induced electro-motoric force may be deduced from this conception in its most general form. This shows again that electro-dynamic forces are subject to the same general principles of action as common mechanical forces.

The two volumes lately published by Professor Maxwell contain not only this new theory, but a very complete, methodical, and clear exposition of all those parts of electric science which could be brought under precise theoretical conceptions, and be developed mathematically. He has done a great service by this work to every student of physics. Hitherto we were obliged to search after the papers treating the different parts of this subject through a great number of scientific periodicals and books. Besides, in relation to the original parts of the book, principally those treating of the ultimate causes of electro-dynamic action, I do not hesitate to say that I consider his method of forming new theoretical conceptions, which are at the same time perfectly definite in their quantitative determination and yet as general as possible, and not more specified than is needed, or more than our present knowledge of the facts allows, as really a model of cautious scientific progress.

ACTION AT A DISTANCE.

By Professor Clerk Maxwell.

[From the Proceedings of the London Institution.]

I have no new discovery to bring before you this evening. I must ask you to go over very old ground, and to turn your attention to a question which has been raised again and again ever since men began to think.

The question is that of the transmission of force. We see that two bodies at a distance from each other exert a mutual influence on each other's motion. Does this mutual action depend on the existence of some third thing, some medium of communication, occupying the space between the bodies, or do the bodies act on each other immediately without the intervention of anything else?

The mode in which Faraday was accustomed to look at phenomena of this kind differs from that adopted by many other modern inquirers, and my special aim will be to enable you to place yourselves at Faraday's point of view, and to point out the scientific value of that conception of *lines of force* which, in his hands, became the key to the science of electricity.

When we observe one body acting on another at a distance, before we assume that this action is direct and immediate we generally inquire whether there is any material connection between the two bodies; and if we find strings or rods, or mechanism of any kind, capable of accounting for the observed action between the bodies, we prefer to explain the action by means of these intermediate connections rather than to admit the notion of direct action at a distance.

Thus, when we ring a bell by means of a wire, the successive parts of the wire are first tightened and then moved till at last the bell is rung at a distance by a process in which all the intermediate particles of the wire have taken part one after the other. We may ring a bell at a distance in other ways, as by forcing air into a long tube, at the other end of which is a cylinder with a piston which is made to fly out and strike the bell. We may also use a wire; but instead of pulling it we may connect it at one end with a voltaic battery and at the other with an electro-magnet, and thus ring the bell by electricity.

Here are three different ways of ringing a bell. They all agree, however, in the circumstance that between the ringer and the bell there is an unbroken line of communication, and that at every point of this line some physical process goes on by which the action is transmitted from one end to the other. The process of transmission is not instantaneous but gradual; so that there is an interval of time after the impulse has been given to one extremity of the line of communication, during which the impulse is on its way, but has not reached the other end.

It is clear, therefore, that in many cases the action between bodies at a distance may be accounted for by a series of actions between each successive pair of a series of bodies which occupy the intermediate space;

and it is asked, by the advocates of mediate action, whether, in those cases in which we cannot perceive the intermediate agency, is it not more philosophical to admit the existence of a medium which we cannot at present perceive than to assert that a body can act at a place where it is not?

To a person ignorant of the properties of air, the transmission of force by means of that invisible medium would appear as unaccountable as any other example of action at a distance, and yet in this case we can explain the whole process and determine the rate at which the action is passed on from one portion to another of the medium.

Why, then, should we not admit that the familiar mode of communicating motion by pushing and pulling with our hands is the type and exemplification of all action between bodies, even in cases in which we can observe nothing between the bodies which appears to take part in the action?

Here, for instance, is a kind of attraction with which Professor Guthrie has made us familiar. A disk is set in vibration, and is then brought near a light suspended body, which immediately begins to move toward the disk, as if drawn toward it by an invisible cord. What is this cord?

Sir W. Thomson has pointed out that in a moving fluid the pressure is least where the velocity is greatest. The velocity of the vibratory motion of the air is greatest nearest the disk. Hence the pressure of the air on the suspended body is less on the side nearest the disk than on the opposite side; the body yields to the greater pressure, and moves toward the disk.

The disk, therefore, does not act where it is not. It sets the air next it in motion by pushing it, this motion is communicated to more and more distant portions of the air in turn, and thus the pressures on opposite sides of the suspended body are rendered unequal, and it moves toward the disk in consequence of the excess of pressure. The force is, therefore, a force of the old school—a case of *vis à tergo*, a shove from behind.

The advocates of the doctrine of action at a distance, however, have not been put to silence by such arguments. What right, say they, have we to assert that a body cannot act where it is not? Do we not see an instance of action at a distance in the case of a magnet, which acts on another magnet not only at a distance, but with the most complete indifference to the nature of the matter which occupies the intervening space? If the action depends on something occupying the space between the two magnets, it cannot surely be a matter of indifference whether this space is filled with air or not, or whether wood, glass, or copper be placed between the magnets.

Besides this, Newton's law of gravitation, which every astronomical observation only tends to establish more firmly, asserts not only that the heavenly bodies act on one another across immense intervals of space, but that two portions of matter, the one buried a thousand miles

deep in the interior of the earth, and the other a hundred thousand miles deep in the body of the sun, act on one another with precisely the same force as if the strata beneath which each is buried had been non-existent. If any medium takes part in transmitting this action, it must surely make some difference whether the space between the bodies contains nothing but this medium, or whether it is occupied by the dense matter of the earth or of the sun.

But the advocates of direct action at a distance are not content with instances of this kind, in which the phenomena, even at first sight, appear to favor their doctrine. They push their operations into the enemy's camp, and maintain that even when the action is apparently the pressure of contiguous portions of matter, the contiguity is only apparent—that a space *always* intervenes between the bodies which act on each other. They assert, in short, that so far from action at a distance being impossible, it is the only kind of action which ever occurs, and that the favorite old *vis à tergo* of the schools has no existence in nature, and exists only in the imagination of schoolmen.

The best way to prove that when one body pushes another it does not touch it is to measure the distance between them. Here are two glass lenses, one of which is pressed against the other by means of a weight. By means of the electric light we may obtain on the screen an image of the place where the one lens presses against the other. A series of colored rings is formed on the screen. These rings were first observed and first explained by Newton. The particular color of any ring depends on the distance between the surfaces of the pieces of glass. Newton formed a table of the colors corresponding to different distances, so that by comparing the color of any ring with Newton's table we may ascertain the distance between the surfaces of that ring. The colors are arranged in rings because the surfaces are spherical, and, therefore, the interval between the surfaces depends on the distance from the line joining the centers of the spheres. The central spot of the rings indicates the place where the lenses are nearest together, and each successive ring corresponds to an increase of about the four thousandth part of a millimeter in the distance of the surfaces.

The lenses are now pressed together with a force equal to the weight of an ounce; but there is still a measurable interval between them, even at the place where they are nearest together. They are not in optical contact. To prove this I apply a greater weight. A new color appears at the central spot, and the diameters of all the rings increase. This shows that the surfaces are now nearer than at first, but they are not yet in optical contact, for, if they were, the central spot would be black; I therefore increase the weights, so as to press the lenses into optical contact.

But what we call optical contact is not real contact. Optical contact indicates only that the distance between the surfaces is much less than a wave-length of light. To show that the surfaces are not in real con-

tact, I remove the weights. The rings contract, and several of them vanish at the center. Now, it is possible to bring two pieces of glass so close together that they will not tend to separate at all, but adhere together so firmly that, when torn asunder, the glass will break, not at the surface of contact, but at some other place. The glasses must then be many degrees nearer than when in mere optical contact.

Thus we have shown that bodies begin to press against each other while still at a measurable distance, and that even when pressed together with great force they are not in absolute contact, but may be brought nearer still, and that by many degrees.

Why, then, say the advocates of direct action, should we continue to maintain the doctrine, founded only on the rough experience of a pre-scientific age, that matter cannot act where it is not, instead of admitting that all the facts from which our ancestors concluded that contact is essential to action were in reality cases of action at a distance, the distance being too small to be measured by their imperfect means of observation?

If we are ever to discover the laws of nature, we must do so by obtaining the most accurate acquaintance with the facts of nature, and not by dressing up in philosophical language the loose opinions of men who had no knowledge of the facts which throw most light on these laws. And as for those who introduce ethereal or other media, to account for these actions, without any direct evidence of the existence of such media, or any clear understanding of how the media do their work, and who fill all space three and four times over with ethers of different sorts, why the less these men talk about their philosophical scruples about admitting action at a distance the better.

If the progress of science were regulated by Newton's first law of motion, it would be easy to cultivate opinions in advance of the age. We should only have to compare the science of to-day with that of fifty years ago; and by producing, in the geometrical sense, the line of progress, we should obtain the science of fifty years hence.

The progress of science in Newton's time consisted in getting rid of the celestial machinery with which generations of astronomers had incumbered the heavens, and thus "sweeping cobwebs off the sky."

Though the planets had already got rid of their crystal spheres, they were still swimming in the vortices of Descartes. Magnets were surrounded by effluvia, and electrified bodies by atmospheres, the properties of which resembled in no respect those of ordinary effluvia and atmospheres.

When Newton demonstrated that the force which acts on each of the heavenly bodies depends on its relative position with respect to the other bodies, the new theory met with violent opposition from the advanced philosophers of the day, who described the doctrine of gravitation as a return to the exploded method of explaining everything by occult causes, attractive virtues, and the like.

Newton himself, with that wise moderation which is characteristic of all his speculations, answered that he made no pretense of explaining the mechanism by which the heavenly bodies act on each other. To determine the mode in which their mutual action depends on their relative position was a great step in science, and this step Newton asserted that he had made. To explain the process by which this action is effected was quite a distinct step, and this step Newton, in his Principia, does not attempt to make.

But so far was Newton from asserting that bodies really do act on one another at a distance, independently of anything between them, that in a letter to Bentley, which has been quoted by Faraday in this place, he says:

"It is inconceivable that inanimate brute matter should, without the mediation of something else which is not material, operate upon and affect other matter without mutual contact, as it must do if gravitation, in the sense of Epicurus, be essential and inherent in it. That gravity should be innate, inherent, and essential to matter, so that one body can act upon another at a distance, through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

Accordingly, we find, in his Optical Queries and in his letters to Boyle, that Newton had very early made the attempt to account for gravitation by means of the pressure of a medium, and that the reason he did not publish these investigations "proceeded from hence only, that he found he was not able, from experiment and observation, to give a satisfactory account of this medium, and the manner of its operation in producing the chief phenomena of nature."*

The doctrine of direct action at a distance cannot claim for its author the discoverer of universal gravitation. It was first asserted by Roger Cotes, in his preface to the Principia, which he edited during Newton's life. According to Cotes, it is by experience that we learn that all bodies gravitate. We do not learn in any other way that they are extended, movable, or solid. Gravitation, therefore, has as much right to be considered an essential property of matter as extension, mobility, or impenetrability.

And when the Newtonian philosophy gained ground in Europe, it was the opinion of Cotes rather than that of Newton that became most prevalent, till at last Boscovich propounded his theory, that matter is a congeries of mathematical points, each endowed with the power of attracting or repelling the others according to fixed laws. In his world, matter is unextended and contact impossible. He did not forget, however, to endow his mathematical points with inertia. In this some of the modern representatives of his school have thought that he "had

* Maclaurin's Account of Newton's Discoveries.

not quite got so far as the strict modern view of 'matter' as being but an expression for modes or manifestations of 'force.'"*

But if we leave out of account for the present the development of the ideas of science, and confine our attention to the extension of its boundaries, we shall see that it was most essential that Newton's method should be extended to every branch of science to which it was applicable—that we should investigate the forces with which bodies act on each other in the first place, before attempting to explain *how* that force is transmitted. No men could be better fitted to apply themselves exclusively to the first part of the problem than those who considered the second part quite unnecessary.

Accordingly, Cavendish, Coulomb, and Poisson, the founders of the exact sciences of electricity and magnetism, paid no regard to those old notions of "magnetic effluvia" and "electric atmospheres" which had been put forth in the previous century, but turned their undivided attention to the determination of the law of force according to which electrified and magnetized bodies attract or repel each other. In this way the true laws of these actions were discovered. And this was done by men who never doubted that the action took place at a distance, without the intervention of any medium, and who would have regarded the discovery of such a medium as complicating rather than as explaining the undoubted phenomena of attraction.

We have now arrived at the great discovery by Oersted of the connection between electricity and magnetism. Oersted found that an electric current acts on a magnetic pole, but that it neither attracts it nor repels it, but causes it to move round the current. He expressed this by saying that "the electric conflict acts in a revolving manner."

The most obvious deduction from this new fact was that the action of the current on the magnet is not a push-and-pull force, but a rotatory force, and accordingly many minds were set a speculating on vortices and streams of ether whirling round the current.

But Ampère, by a combination of mathematical skill with experimental ingenuity, first proved that two electric currents act on one another, and then analyzed this action into the resultant of a system of push-and-pull forces between the elementary parts of these currents.

The formula of Ampère, however, is of extreme complexity as compared with Newton's law of gravitation, and many attempts have been made to resolve it into something of greater apparent simplicity.

I have no wish to lead you into a discussion of any of these attempts to improve a mathematical formula. Let us turn to the independent method of investigation employed by Faraday in those researches in electricity and magnetism which have made this institution one of the most venerable shrines of science.

No man ever more conscientiously and systematically labored to improve all his powers of mind than did Faraday from the very beginning

* Review of Mrs. Somerville, "Saturday Review," February 13, 1869, vol. vii, No. 58.

of his scientific career. But whereas the general course of scientific method then consisted in the application of the ideas of mathematics and astronomy to each new investigation in turn, Faraday seems to have had no opportunity of acquiring a technical knowledge of mathematics, and his knowledge of astronomy was mainly derived from books.

Hence, though he had a profound respect for the great discovery of Newton, he regarded the attraction of gravitation as a sort of sacred mystery, which, as he was not an astronomer, he had no right to gainsay or to doubt, his duty being to believe it in the exact form in which it was delivered to him. Such a dead faith was not likely to lead him to explain new phenomena by means of direct attractions.

Besides this, the treatises of Poisson and Ampère are of so technical a form that to derive any assistance from them the student must have been thoroughly trained in mathematics, and it is very doubtful if such a training can be begun with advantage in mature years.

Thus Faraday, with his penetrating intellect, his devotion to science, and his opportunities for experiments, was debarred from following the course of thought which had led to the achievements of the French philosophers, and was obliged to explain the phenomena to himself by means of a symbolism which he could understand, instead of adopting what had hitherto been the only tongue of the learned.

This new symbolism consisted of those lines of force extending themselves in every direction from electrified and magnetic bodies, which Faraday in his mind's eye saw as distinctly as the solid bodies from which they emanated.

The idea of lines of force and their exhibition by means of iron filings was nothing new. They had been observed repeatedly, and investigated mathematically as an interesting curiosity of science. But let us hear Faraday himself, as he introduces to his reader the method which in his hands became so powerful:*

"It would be a voluntary and unnecessary abandonment of most valuable aid if an experimentalist who chooses to consider magnetic power as represented by lines of magnetic force were to deny himself the use of iron filings. By their employment he may make many conditions of the power, even in complicated cases, visible to the eye at once; may trace the varying direction of the lines of force and determine the relative polarity; may observe in which direction the power is increasing or diminishing; and in complex systems may determine the neutral points or places where there is neither polarity nor power, even when they occur in the midst of powerful magnets. By their use probable results may be seen at once, and many a valuable suggestion gained for future leading experiments."

Experiment on lines of force.

In this experiment each filing becomes a little magnet. The poles of opposite names belonging to different filings attract each other and

* Experimental Researches, 3284.

stick together, and more filings attach themselves to the exposed poles; that is, to the ends of the row of filings. In this way the filings, instead of forming a confused system of dots over the paper, draw together, filing to filing, till long fibers of filings are formed, which indicate by their direction the lines of force in every part of the field.

The mathematicians saw in this experiment nothing but a method of exhibiting at one view the direction in different places of the resultant of two forces, one directed to each pole of the magnet, a somewhat complicated result of the simple law of force.

But Faraday, by a series of steps as remarkable for their geometrical definiteness as for their speculative ingenuity, imparted to his conception of these lines of force a clearness and precision far in advance of that with which the mathematicians could then invest their own formulas.

In the first place, Faraday's lines of force are not to be considered merely as individuals, but as forming a system, drawn in space in a definite manner, so that the number of the lines which pass through an area, say of one square inch, indicates the intensity of the force acting through the area. Thus the lines of force become definite in number. The strength of a magnetic pole is measured by the number of lines which proceed from it; the electro-tonic state of a circuit is measured by the number of lines which pass through it.

In the second place, each individual line has a continuous existence in space and time. When a piece of steel becomes a magnet, or when an electric current begins to flow, the lines of force do not start into existence, each in its own place, but, as the strength increases, new lines are developed within the magnet or current, and gradually grow outward, so that the whole system expands from within, like Newton's rings in our former experiment. Thus, every line of force preserves its identity during the whole course of its existence, though its shape and size may be altered to any extent.

I have no time to describe the methods by which every question relating to the forces acting on magnets or on currents, or to the induction of currents in conducting circuits, may be solved by the consideration of Faraday's lines of force. In this place they can never be forgotten. By means of this new symbolism, Faraday defined with mathematical precision the whole theory of electro-magnetism, in language free from mathematical technicalities, and applicable to the most complicated as well as the simplest cases. But Faraday did not stop here. He went on from the conception of geometrical lines of force to that of physical lines of force. He observed that the motion which the magnetic or electric force tends to produce is invariably such as to shorten the lines of force, and to allow them to spread out laterally from each other. He thus perceived in the medium a state of stress, consisting of a tension, like that of a rope, in the direction of the lines of force, combined with a pressure in all directions at right angles to them.

This is quite a new conception of action at a distance, reducing it to

a phenomenon of the same kind as that action at a distance which is exerted by means of the tension of ropes and the pressure of rods. When the muscles of our bodies are excited by that stimulus which we are able in some unknown way to apply to them, the fibers tend to shorten themselves and at the same time to expand laterally. A state of stress is produced in the muscle, and the limb moves. This explanation of muscular action is by no means complete. It gives no account of the cause of the excitement of the state of stress, nor does it even investigate those forces of cohesion which enable the muscles to support this stress. Nevertheless, the simple fact that it substitutes a kind of action which extends continuously along a material substance for one of which we know only a cause and an effect at a distance from each other, induces us to accept it as a real addition to our knowledge of animal mechanics.

For similar reasons we may regard Faraday's conception of a state of stress in the electro-magnetic field as a method of explaining action at a distance by means of the continuous transmission of force, even though we do not know how the state of stress is produced.

But one of Faraday's most pregnant discoveries, that of the magnetic rotation of polarized light, enables us to proceed a step farther. The phenomenon, when analyzed into its simplest elements, may be described thus: Of two circularly-polarized rays of light, precisely similar in configuration, but rotating in opposite directions, that ray is propagated with the greater velocity which rotates in the same direction as the electricity of the magnetizing current.

It follows from this, as Sir W. Thomson has shown by strict dynamical reasoning, that the medium, when under the action of magnetic force, must be in a state of rotation; that is to say, that small portions of the medium, which we may call molecular vortices, are rotating each on its own axis, the direction of this axis being that of the magnetic force.

Here, then, we have an explanation of the tendency of the lines of magnetic force to spread out laterally and to shorten themselves. It arises from the centrifugal force of the molecular vortices.

The mode in which electro-motive force acts in starting and stopping the vortices is more abstruse, though it is, of course, consistent with dynamical principles.

We have thus found that there are several different kinds of work to be done by the electro-magnetic medium if it exists. We have also seen that magnetism has an intimate relation to light, and we know that there is a theory of light which supposes it to consist of the vibrations of a medium. How is this luminiferous medium related to our electro-magnetic medium?

It fortunately happens that electro-magnetic measurements have been made, from which we can calculate, by dynamical principles, the velocity of propagation of small magnetic disturbances in the supposed electro-magnetic medium.

This velocity is very great, from 175,000 to 200,000 miles per second, according to different experiments. Now, the velocity of light, according to Foucault's experiments, is 185,000 miles per second. In fact, the different determinations of either velocity differ from each other more than the estimated velocity of light does from the estimated velocity of propagation of small electro-magnetic disturbance. But if the luminiferous and the electro-magnetic media occupy the same place, and transmit disturbances with the same velocity, what reason have we to distinguish the one from the other? By considering them as the same, we avoid at least the reproach of filling space twice over with different kinds of ether.

Besides this, the only kind of electro-magnetic disturbances which can be propagated through a non-conducting medium is a disturbance transverse to the direction of propagation, agreeing in this respect with what we know of that disturbance which we call light. Hence, for all we know, light also may be an electro-magnetic disturbance in a non-conducting medium. If we admit this, the electro-magnetic theory of light will agree in every respect with the undulatory theory, and the work of Thomas Young and Fresnel will be established on a firmer basis than ever when joined with that of Cavendish and Coulomb by the keystone of the combined sciences of light and electricity—Faraday's great discovery of the electro-magnetic rotation of light.

The vast interplanetary and interstellar regions will no longer be regarded as waste places in the universe, which the Creator has not seen fit to fill with the symbols of the manifold order of his kingdom, We shall find them to be already full of this wonderful medium; so full that no human power can remove it from the smallest portion of space, or produce the slightest flaw in its infinite continuity. It extends unbroken from star to star; and when a molecule of hydrogen vibrates in the Dog-star, the medium receives the impulses of these vibrations; and after carrying them in its immense bosom for three years, delivers them in due course, regular order, and full tale into the spectroscope of Mr. Huggins, at Tulse Hill.

But the medium has other functions and operations, besides bearing light from man to man, and from world to world, and giving evidence of the absolute unity of the metric system of the universe. Its minute parts may have rotary as well as vibratory motions, and the axes of rotation form those lines of magnetic force which extend in unbroken continuity into regions which no eye has seen, and which by their action on our magnets are telling us, in language not yet interpreted, what is going on in the hidden under-world from minute to minute and from century to century.

And these lines must not be regarded as mere mathematical abstractions. They are the directions in which the medium is exerting a tension like that of a rope, or rather like that of our own muscles. The tension of the medium in the direction of the earth's magnetic force is

in this country one grain weight on eight square feet. In some of Dr. Joule's experiments, the medium has exerted a tension of 200 pounds weight per square inch.

But the medium, in virtue of the very same elasticity by which it is able to transmit the undulations of light, is also able to act as a spring. When properly wound up, it exerts a tension different from the magnetic tension, by which it draws oppositely electrified bodies together, produces effects through the length of telegraphic wires, and, when of sufficient intensity, leads to the rupture and explosion called lightning.

These are some of the already discovered properties of that which has often been called vacuum, or nothing at all. They enable us to resolve several kinds of action at a distance into actions between contiguous parts of a continuous substance. Whether this resolution is of the nature of explication or complication, I must leave to the metaphysicians.

AN ACCOUNT OF THE ASTRONOMICAL OBSERVATORY AT CORDOBA, ARGENTINE REPUBLIC.

An address to citizens of Boston by DR. B. A. GOULD, *the Director.*

More than half a century ago the great astronomer Bessel undertook the formation of a catalogue which should contain the positions and magnitudes of as many stars as possible between the parallels of 45° north declination and 15° south, down to the ninth magnitude; thus including all stars one-fifteenth part as bright as the faintest which he could discern with the naked eye. This great work he carried to a successful conclusion; commencing the observations in 1821 and completing them in 1833, and securing more than 72,000 observations of 62,380 different stars. These have since been carefully computed, and the resultant catalogues published by the Imperial Observatory of Russia, at the public expense, affording a priceless aid to astronomers. In France an analogous attempt had been made near the close of the last century, by La Lande, who undertook a scrutiny of all the stars between the north pole and the southern tropic, and his 47,000 observations have been computed and published at the expense of the British government; but the superiority of modern instruments and methods rendered Bessel's undertaking essentially a new one.

Later, his pupil and assistant, Argelander, upon whom his mantle had fallen, extended his scrutiny by two more series of zone-observations—one on the north, reaching from 45° to 80°, the other on the south from 15° to 31°, the two jointly containing about 50,000 observations. The vicinity to the pole upon the one side and to the horizon on the other, presented peculiar difficulties, yet the continued improvement of astronomical instruments and methods, and the rare skill of Argelander, enabled him to attain both a somewhat higher degree of accuracy and a relatively greater number of observations. Thus, in 1852, the heavens had been well studied from 80° north of the equator to 31° south; and when in that year our lamented countryman, Gilliss, returned from his expedition to Chile, he brought with him the manuscript results of an extensive series of zones, which he had observed around the south pole. Soon afterward, the English astronomer, Carrington, explored the ten degrees around the north pole; so that for the last eighteen years the only region of the heavens which has not been carefully investigated is that which lies between the parallel of 31° south and the northern limit of Gilliss's yet unpublished observations. To fill this hiatus and complete the survey of the heavens on some plan

analogous to that of Bessel and Argelander was naturally an alluring problem.

The singularity and strange beauty of some portions of the southern sky has from the first attracted the attention of navigators. At the very beginning of the sixteenth century the luminous patches now called the "Magellanic clouds," as well as the "Coal-sacks," those dark blots upon the brilliant milky-way, had been vividly portrayed; and even Amerigo Vespucci boasted that he had looked upon the four stars which, according to Dante, had been

> "Ne'er seen before, save by the primal people,"

but which have been now, for more than three centuries and a half, renowned in song and story under the name of the "Southern Cross." Nor need we wonder at the poet's fervor when he adds:

> "Rejoicing in the flamelets seemed the heaven.
> O thou septentrional and widowed site,
> In that thou art deprived of seeing these!"

The glory of the southern sky in the region near the Cross is indescribable. There, where the Milky Way is crossed by the thick stream of bright stars which skirts this river of light, its brilliancy is wondrously increased, and it exhibits a magnificence unequaled in any other portion of the heavens. There glitter a multitude of bright stars, more thickly scattered than in any region within our northern view, while the background is gorgeous in its splendor. Often, on some clear night, when this region has suddenly been brought to my view in passing some edifice, or turning some street-corner, I have stood amazed at the flood of light which it diffused; and often, too, when leaving the observatory in the early morning-hours after a night of wearying labor, I have felt reluctant to abandon the magnificent spectacle, for the sake of much-needed repose. In close proximity are the rich constellations of the Centaur, the Keel and Sails of the ship Argo, and the Wolf; and the glory reaches through the Altar even to the southern portion of the Scorpion. There extend large tracts which rival the Pleiades in the profusion of their stars, gleaming upon a background of nebula. Elsewhere the southern heavens are not so brilliant as the northern, nor do they contain so many stars as bright as the faintest which we can discern; but there is nothing between the two poles comparable in beauty with the tract to which I refer.

Yet the earliest accurate observations of southern stars were those of Halley, afterwards Astronomer Royal of England, who visited St. Helena for the purpose between the years 1676 and 1678, under the patronage of King Charles II and the East India Company, and there determined the positions of 341 stars. Seventy-five years later, in 1751, the French astronomer Lacaille undertook a similar expedition to the Cape of Good Hope, then a Dutch colony, at the expense of the French government, and with the official support of the French

Academy of Sciences, the States-General of Holland, and the Prince of Orange. With but one assistant, and only employing a little telescope half an inch in aperture and twenty-eight inches in focal length, strapped to the tube of a mural quadrant, he succeeded in determining the positions of 9,766 stars, between the tropic and the pole, in the short period of less than eleven months; but his observations were not published until eleven years later, and then in so crude a form that they were with difficulty available until about a quarter-century ago, when they were computed and published, like those of La Lande, at the expense of the British government. These have till now been a principal reliance of astronomers for their knowledge of the southern heavens. I may not dilate on what has been done elsewhere; at Paramatta, where the observations, though laboriously made, have rendered comparatively little service to science; at Madras, 13° north of the equator, where Taylor made excellent observations of some 6,000 southern stars; at the Cape of Good Hope, where observations of great precision and value have been made by various eminent men, and where Sir John Herschel devoted seven years to forming a catalogue of nebulas and double stars; at Saint Helena, where Johnson, one of the most skillful and delicate observers of our times, fixed the position of 606 southern stars; or of the observatory established at Melbourne twenty years ago, from which have emanated observations of the highest quality, and where the director, Mr. Ellery, has commenced a grand study of the southern heavens, upon a different plan from mine in Cordoba, and for a different purpose. To Gilliss's labors in Chile I have already alluded, and at the observatory of Santiago, in that republic, the places of a considerable number of stars have been determined by him and his successors.

Such, my friends, were the circumstances as they presented themselves a few years ago. Argelander's explorations reached only to 31° south, which is but 8° above his horizon, and where his observations were not only difficult, but subject to serious embarrassments from the excessive influence of refraction. Beyond this, no systematic series, aiming at both accuracy in the positions and tolerable completeness, had been attempted since Lacaille's, with poor instruments, a century and a quarter ago, unless we except Gilliss's unpublished observations around the south pole, which future astronomers may or may not see. The only other observations available were the scattered ones already mentioned, in which the aim had been not to fix the places of many stars, so much as by repeated observations of some principal ones to obtain for these the highest accuracy. In all, I scarcely think they included more than about 12,000 different stars.

Information from various sources having led me to believe that the climate of Cordoba, midway between the Atlantic and Pacific, and exempt alike from the frequent tornadoes of the one coast and the earthquakes of the other, was especially favorable for astronomical

research, I addressed a letter, in October, 1865, to Mr. Sarmiento, then Argentine minister to this country, telling him of my desire to make an astronomical expedition thither, and of my hopes of being able to secure the necessary pecuniary means from lovers of science. In this letter I asked him whether such an expedition would be cordially received by the national government and by the people of Cordoba; whether protection would be afforded in case of need; and whether I could reasonably hope that on my own departure the establishment would be adopted by the government and continued as a national institution. His reply was most cordial, answering all my questions favorably, and promising even more than I had ventured to ask; and in due time a full official indorsement was received from the Argentine government, and Doctor Costa, Minister of Public Instruction, in a note dated January, 1866, expressed his regret that the heavy sacrifices which the nation was making, in its mortal struggle with the tyrant Lopez of Paraguay, deprived him of the power of offering yet more effective support to the undertaking. My plan failed at that time, owing to my want of success in obtaining the necessary pecuniary means, yet Mr. Sarmiento's interest in it never flagged; nor did he, when nominated for President eighteen months later, forget the astronomical project amid official cares, educational labors, or political excitement. One of his earliest acts after assuming the presidency in 1868 was to recommend a national observatory. This was voted by the Argentine congress at its first subsequent session; and in the latter half of 1869 I received from Doctor Avellaneda, then Minister of Public Instruction, an invitation to organize a permanent national observatory and provide the needful instruments and buildings; and money-credits were furnished for doing this in an adequate, though unpretending, way. I took the necessary steps as speedily as possible, and a happy combination of circumstances aided the prompt acquisition of instruments, which would else have required a long time for their construction. Happily, as it proved, although it had cost me some regrets in the interval, I had more than three years previously ordered, upon my own responsibility, from the celebrated artist Repsold, of Hamburg, a meridian-circle of dimensions and character especially adapted to the proposed work; and this had been completed but a few months when the opportunity for its employment arrived.

The ready assistance and encouragement which the undertaking received from every side, as soon as it became publicly known, will always afford me delightful remembrances. Not only in its private and personal, but also in its scientific relations—not only by words that meant something, but, likewise, by the most practical actions—aid came to it from all directions. The Superintendent of the Coast Survey hastened to offer the loan of such portable instruments as might be serviceable; an offer which I accepted as freely as it was made. The secretary of the Smithsonian Institution did the same; and both these institutions, as well

as the Naval Observatory and the Nautical Almanac office, contributed full series of all their publications. By some grievous mischance the boxes containing these invaluable books never reached their destination, but the loss has been repaired to a considerable extent by new gifts. The American Academy of this city lent money, from its Rumford fund, to purchase apparatus for studying the light of the stars, and gave me permission to return either the instruments or the money, and at the most convenient time. Four of the scientific societies of England, the observatories of Greenwich, Pulkowa, and Leipzig, astronomers in England, France, Germany, Russia, and Italy, sent such generous gifts of valuable books, maps, charts, &c., that the faintest heart could not have failed to gather courage. Not to mention my own countrymen and all I owe them, Professors Bruhns and Zöllner in Leipzig undertook to superintend the construction of instruments for the new institution; and, during the whole period of my absence, the former has attended to all the apparatus and books which I desired from Germany. So, too, Professor Auwers in Berlin took charge of extensive computations which I needed to have made in some place where professional computers could be found. And, from the beginning of my labors to the present time, I have been encouraged and aided by the sympathy and counsel of my revered friend, Professor Argelander.

The means available for procuring the necessary assistance were insufficient to permit the engagement of trained astronomers, and it was an especial disappointment that I was unable to secure the companionship of any of my own former pupils or assistants, whose aid in such an enterprise would have been doubly valuable. But I did secure the aid of four very capable and well-educated young men, recently graduated, three from Pennsylvania and one from New England. These gentlemen sailed for Buenos Ayres direct, while I went by way of Europe, and we reached our destinations at about the same time.

It was the 25th August, 1870, when I arrived in Buenos Ayres with my family, and from that day until that on which I left the same pleasant capital just two months ago, our history is a record of private kindness and public generosity.

Thence we ascended the La Plata, threading an exquisite maze of beautiful and closely crowded islands, decked with the dark-green foliage and glowing fruit of the orange; through narrow channels guarded by luxuriant willows, whose trailing branches swept our decks; amid jungles sheltering unnumbered alligators and countless tigers; and then, entering the vast delta of the Parana, moved up that stately river for about twenty hours; now descrying on its western bank the buildings of some large pastoral estate, and now touching at some one of the embryo cities which are, at no distant day, to become flourishing sea-ports and centers of an active commerce.

In the thriving town of Rosario, 250 miles above Buenos Ayres, we found a hospitable welcome at the house of our distinguished country-

man, Mr. Wheelwright, whose energy and enterprise had given to South America her first steamboat, first railroad, first telegraph, first water-works, and first gas-illumination; and on the day following we traversed the pampa westward for yet another 250 miles, over the railway which he had just completed, and which had been inaugurated a few weeks before. For the second time within two years, we raced with the antelopes, and saw the prairie dogs and owls amicably seated at the threshold of their common dwelling. Ostriches were running at speed across the boundless and level expanse; herds with thousands of cattle, and flocks with tens of thousands of sheep, roamed at will, ignorant of all restraint. The sparse settlements could be seen for a dozen or more miles away, their whitewashed walls and their few trees arresting the attention on the horizon of this terrestrial ocean, just as a distant sail fixes the gaze of a seaman. At intervals the ground was scarlet or white or purple with great patches of verbena or portulacca; the taller shrubs served as trellises for the passion-flower or the white bignonia; and many of our most favorite exotics studded the prairie with brilliant colors.

Sixteen hours brought us to the western limit of the pampa, and to the city of Cordoba, the goal of 10,000 miles of journeying, where still another cordial welcome awaited us. Here the provincial, or as we call it the state, government empowered me to select for the observatory whatever site might appear to me most desirable, and I chose one upon the high pampa level, at the brink of the precipitous declivity bordering the valley in which the city lies, 120 feet below. The floor of the observatory is on a level with the crosses upon the high church-towers, three-quarters of a mile away.

Such portions of the building as could be constructed of wood or metal had been made at home, and forwarded by vessel, and it was my expectation that all the work of construction would be completed in three months, so that the observations could begin early in 1871. But the Cordobese workmen had enjoyed no Yankee apprenticeship, and it was not until July that the first dome was completed. We celebrated the Fourth by mounting the equatorial—an instrument of American construction, the joint work of the optician Fitz and of our neighbor Alvan Clark. Meantime the instruments and books from Europe had suffered unprecedented delays. Some were on a French ship, and some on German vessels, and all were blockaded for many months by the war, which had been declared a day or two before we sailed from Liverpool, and the first tidings of which were received after our arrival in Cordoba. The war over, the ship with the meridian circle was frozen up for the winter in the Elbe. When at last it reached Buenos Ayres, the port was practically closed and the city laid waste by the yellow fever, and many more months elapsed before the quarantine was removed which closed the interior against the capital in conformity with the yet prevalent traditionary prejudices inherited from Spain, and which are so interwoven with all the popular ideas that more than one

generation will probably pass before they disappear. Thus season after season passed away, and it was not till May, 1872, that the meridian-circle was mounted ready for use, nor until the 9th of September, 1872, that the regular observations were commenced for the celestial survey which I had planned seven years before.

But this long delay proved in the end not to have been a misfortune, irksome as it was. Within the first month it became evident that the construction of the building would demand a disproportionate amount of time and attention, and that although the large telescope might be employed to some extent, a long time must elapse before the work with the meridian-circle could begin. Although I little dreamed how great would be the delay, I determined to use this opportunity for the construction of a uranometry, or catalogue of all the visible stars of the southern sky, with an exact determination of the brilliancy of each. The labor of these first eighteen months was certainly as assiduous and fruitful, and I believe it was as serviceable to science, as the later work. Thirty years before, Argelander had made such a uranometry, giving the brightness of each star to the nearest third of a unit of magnitude. In Albany, in 1858, we had done the same work, for a portion of the heavens, to tenths of a magnitude, while awaiting the mounting of the instruments. These observations, although stereotyped at the time, have never been published; but they had given me a good deal of experience, which now became very useful.

Thus the scientific labors of the first year went to the construction of star-lists and charts of the visible heavens, as they appeared on the clearest nights to the sharpest unassisted eyes, the magnitudes being estimated to tenths of a unit. No instruments were used other than common opera-glasses; but the purity of the air at Cordoba, and an elevation of about 1,300 feet above the sea-level, give a remarkable transparency to the atmosphere on favorable nights. My own near-sightedness precluded me from taking part in the actual observations, but I found more than enough to do in identifying those stars whose places had been determined by previous astronomers, in providing for our own future observation of those not to be found in the catalogues, in maintaining a uniform system of estimates by the four observers, and in the general management of the work. Every test in my power was brought to bear upon the accuracy of the work as it progressed, and each scrutiny served to confirm my confidence in the carefulness of all engaged in the observations. After the completion of this undertaking, the results were subjected to careful revision by repeating the whole process in a somewhat different form, assigning to each of the observers a region which in the first scrutiny had been given to some other one. The definite results are now available for publication, and the Argentine government has authorized me to make the necessary arrangements. The published work will consist of an atlas of the heavens, from 10° north of the equator to the south pole, showing every star to the seventh mag-

nitude inclusive, and no others, and accompanied by the corresponding catalogues. As a matter of simple justice and propriety, I have given it the name of *Uranometria Argentina*. The magnitude of each star has been determined on the average by more than four observations, and by as many as three different observers. At present, Mr. Thome, whom I have left in charge of the observatory, and who is the only one of the original corps now remaining in Cordoba, is engaged in a last systematic scrutiny of the finished work, to insure that no star is either omitted or wrongly placed. Much more than a quarter part of the actual observation has been done by him; and from his constant and assiduous devotion to the undertaking for nearly four years, I am sure that he now possesses a greater personal familiarity with the southern sky than any man ever attained before. Nor does this comparison in the least diminish the honor due to his late colleagues, to whom a large portion of the excellence of the work must justly be attributed. Of another assistant, not on the observatory's books, but without whose untiring and devoted aid my work could scarcely have been accomplished, I may not speak.

Less than two years ago there was published by Professor Heis a new uranometry of the northern sky, precisely on the same plan as Argelander's, of which it is, in fact, an enlargement, with the addition of fainter stars seen with his unassisted eye, which is of exceptional strength. My plan was somewhat different, and we availed ourselves of opera-glasses to obtain more accurate estimates; and after I found the stars of the seventh magnitude as distinctly visible at Cordoba to eyes of average power, I fixed this magnitude as the limit for the uranometry, a large number of fainter stars being excluded, although their magnitudes have been well determined. If we only consider stars as bright as the sixth magnitude, Heis found 3,139 of these in the northern half of the sky, while we have only three-quarters as many in the southern half. Yet while he has in all 4,909 northern stars, we have 7,670 southern ones, so great is the difference between the transparency of the sky at Cordoba and at Münster. The number of stars in the whole sky visible to the naked eye has usually been estimated at about 5,500. Heis estimates that there are about 6,800 of a brightness not inferior to the faintest which he can see. But I now find that if the sky was as transparent as that at Cordoba on a good night, even an average eye would probably discern not much less than 15,000 in the full circuit of the heavens. The *Uranometria Argentina* contains 8,522 stars, of which 7,670 are situated in the southern heavens, and 852, or just one-tenth of the whole, are within the first ten degrees of north declination.

In connection with the uranometry, an opportunity presented itself to introduce, or rather to suggest to astronomers for their acceptance, a greatly-needed reform in the arrangement and boundaries of the southern constellations, which have from the beginning been in a state of such confusion as to call forth continual complaints from those who

have had to deal with them, and which are depicted alike in no two different maps or globes within my knowledge. I have now re-arranged the whole system in such a manner that the boundaries of the constellations shall be formed, so far as possible, by meridians and parallels of declination, and have found it practicable to arrange this with almost insignificant disturbance of the nomenclature of the principal stars. To this portion of the labor, also, I attach considerable value.

The meridian circle possesses essentially the same optical power as the instruments employed by Bessel and Argelander, the object-glass having an aperture of 4½ Paris inches. But methods of observation have made considerable advance in twenty years, and this new instrument is supplied with varous conveniences which the others did not possess. The principal difference of method, however, is in the employment of the chronographic method of observing transits, the instants of these being registered by telegraphic signals upon a cylinder revolving at a uniform rate. The fundamental plan of all the zone observations of which I have spoken consists in restricting the vertical motion of the telescope to narrow limits proviously assigned, and then determining the moment of transit and the declination of every star that traverses the field within these limits, which of course regulate the width of a strip or "zone" of the heavens, whose length is determined by the duration of the process. It is manifest that the width of the zone can be so chosen that only a small portion of the stars of sufficient magnitude can escape detection. Thus, beginning each zone where the adjacent one ends, the whole region in question is gradually explored.

The most essential point in which the plan of my undertaking differed from that of previous observers, is, that it was my aim to make the determinations absolute, instead of relative. The principle adopted more or less completely in former series has been, in fact, to observe an entire zone in such a way as to determine the differences of the several stars among themselves, and then, identifying those whose positions may be found in catalogues already existing, to calculate the places of the new stars from those of the others. Such had been my own original plan; but I soon became convinced that a sufficient number of star-places of the needful precision was not accessible, and that it was desirable to keep the work independent of any previous catalogue, aiming at what is called an *absolute* determination of the stars observed—that is to say, an entire independence of the work of all other astronomers, outside of the data in the astronomical almanacs. This implied a great increase of labor, since it would demand nearly an hour of additional observations, before and after every zone, for the sole purpose of ascertaining the needful corrections to the indications of the instrument and the clock, which vary appreciably from hour to hour. It likewise entailed much additional labor in the computations; and it became necessary to prepare for our use in Cordoba the daily places of fundamental polar stars, which northern observers find calculated to their

hands in the "Nautical Almanac." Still, it was manifestly desirable, and thus the work was arranged. Whenever possible, we observed, each night, three zones with their belongings, which consumed about eight hours—often more. The zones averaged about a hundred minutes in length: more than this strained eye and nerves too much.

It is an exhausting process to lie for this length of time with the eye glued to the telescope—one hand signaling the instants of each star's transit over a group of delicate threads, and the other pointing the telescope by means of a long screw-handle, estimating, at the same time, the magnitude, and calling out the data to be recorded—the udgment being meanwhile kept in active exercise for deciding upon the best order in which to observe the various stars which are within view at once, and the telescope kept in motion over the whole width of the zone, (which is many times wider than the field of view,) in order that as few stars as possible shall pass unobserved. In many zones we thus observed more than 260 stars; in one there were 285, an average of one star to every twenty-one seconds. Nor is the labor much less for the assistant at the microscope. He must be on the alert to measure and record the reading of the graduated circle as soon as the telescope is pointed; must record the magnitude and groups for each star, as well as the approximate moment from the clock-face, to prevent danger of confusion when his record comes to be combined with that upon the chronograph. And, what is more, he must watch the various pieces of apparatus to see that nothing goes amiss, for chronographs will run down, pen-points will clog and cease to mark, and telegraphic connections will sometimes give out; and when they do, it is always at some critical moment. The quickness and dexterity which the assistants acquired was a source of astonishment and delight to me; and, should our results prove to be what I hope and believe they will, there is no one of the five gentlemen who have at different times taken part in this labor, who may not feel a just pride, not only in the conscientious fidelity with which he performed his part, but also in the skill which he attained in most difficult operations.

A full night's work consisted of three zones, with four series of observations for instrumental corrections. All the zones, and the last series of determining stars, I observed myself; and, until the last few months, the first series also. Between the zones I gave rest to my eyes. The remainder of the work was distributed, as well as might be, among three assistants, in such a way that each should be able to rest his eyes for about an hour and a half on the nights of greatest labor, and also have each third night free. But there was a period of six or eight weeks when our force was temporarily reduced, so that the aid of Messrs. Thome and Bachmann was needed every night. I need not add that just at this time we had a spell of exceptionally clear weather, with only two cloudy nights in a whole month. But there was not the shadow of a complaint, nor was labor ever more cheerfully or cordially

performed than this, which I should hardly have been justified in asking, but was contributed with the readiest good will.

The climate of Cordoba did not correspond with my expectations. Knowing that it was rainless during half the year, and remembering the astonishing continuance of favorable weather which Gilliss had enjoyed in Santiago, I had counted upon an abundance of unclouded sky. But to my sorrow it soon became evident that absence of rain by no means implies absence of clouds; and judging from my memory, I should not estimate the number of good nights in Cordoba as much greater than in Boston; although, to be sure, we should there scarcely be favored with our present experience of a four days' northeaster at midsummer. The sky has provoking tricks of suddenly clouding over just at nightfall, after a magnificent day, or covering itself in a few minutes with a thick veil of mist without previous warning. Thus the rapidity with which the survey progressed has been by no means proportional to the labor expended. Still the conclusion of the first year of the observations in September last showed the gratifying number of 429 zones, containing more than 56,000 observations, and, so far as I could judge, about two-thirds of the region to be explored were disposed of. And it was manifest that, with no better fortune in the weather than in the year past, all the remaining work could be accomplished, and all the unsatisfactory zones repeated in less than a year more. I have not mentioned that the width of the region to be explored had been increased by one-half from my original plan. Instead of taking 29° as the northern limit, and thus lapping 2° upon Argelander's work, I had, at the earnest instance of Argelander himself, commenced at 23°, thus overlapping his zones by 8°, and beginning at a point 16° above the horizon of Bonn; and instead of going only to Gilliss's northern limit at the southern polar circle, the Cordoba zones extend to within 10° of the pole itself, thus covering a belt 57° wide, or about one-third of the whole heavens as measured from pole to pole. On the 13th of April, when my last observation was made, the number of zones observed had reached 619, and the number of star-places was nearly 83,000. These were, furthermore, in the full tide of preparation for the press, five persons being engaged in transcribing and preparing them for computation.

Although the object of labor is not to conquer difficulties—this part of the process being only a means and not an end, and the only proper motive being to secure results—it is pardonable to look back upon the obstacles and impediments, and I can truly say that these have been neither few nor small, nor indeed conquerable, except with the aid of such faithful and able co-workers as I have been favored with. I will not weary you with the tale of all the mishaps, large and small—instruments disturbed, apparatus giving out, tornadoes, dust-storms and the like; of insects in one's nose and eyes and mouth, when the hands could not be used to fight them nor the head moved from the telescope

—but there is one inhabitant of the pampas whose memory can never fade. This is the *vinchuca*, an elder brother of that unnameable insect whom Birdofredum Sawin found running away with his colonel in Mexico; but it is a dozen times longer and broader and thicker, and far more savage. And it has wings. By night this insect comes flying in from all the open country round, and it seems to have a special predilection for astronomers. But for them the observation of the summer zones would have been easier.

The plan of the zones was based, as I have said, upon the fundamental idea that the determinations should be absolute in their character; still it is by no means certain that one observes under the high nervous tension inseparable from such work in the same manner in which he would make a leisurely measurement of the position of an isolated star. It has, therefore, seemed desirable that the positions of not less than six or seven stars in each zone should be determined with all possible accuracy, and by means of repeated observations. With this view I prepared a list of a few thousand stars, whose places were to be measured on not less than four nights, as opportunity should offer; and the intervals between the transits of the fundamental stars, as well those nights or parts of nights on which flying clouds or mists preclude the zone work, although the heavens are partially clear, have been devoted to this class of observations. Already a very considerable amount of material of this sort has been collected and computed, and this work is now going on in my absence.

Among my most cherished hopes, when leaving home, was that of supplementing in the southern hemisphere the remarkable and important results obtained here by our gifted countryman, Mr. Rutherfurd, whose ingenious methods and surpassing skill had enabled him, and him alone, to obtain photographic impressions of star-clusters with a sharpness permitting delicate measurements, as well as to execute these measurements with such an accuracy as to yield results rivaling, if, indeed, not surpassing, those afforded by direct observation with the most elaborate and costly instruments, and with a hundredfold greater expenditure of time. It had been my privilege to subject these measurements for the first time to those numerical computations by which the stellar positions are reduced to the corresponding astronomical form of right-ascensions and declinations, and thus, through the kindness of the valued friend to whom both the new method and its sole results were due, to connect my name in a slight degree with this great step, by determining the relative positions of the principal stars in the Pleiades and the Præsepe from his measures of the photographic plates.

Just before my departure, Mr. Rutherfurd had supplied himself with a yet larger telescope, adapted to the same purpose, and I improved this fortunate opportunity of securing the identical photographic object-glass which he had employed in all his previous investigations. And when I left home it was not without some ground for hoping that a sufficient

sum would soon be contributed from private sources to enable me to carry out the plan of securing photographic impressions of the chief southern star-clusters without appealing to the Observatory or to any other institution. The telescope is adapted for either photographic or optical use, since the two object-glasses are easily interchangeable, and a camera can readily be substituted for the astronomical eye-piece. Immediately on arriving in Buenos Ayres I explained these plans to the President and Minister, and received their cordial promise of all needful aid—promises which, like all others from the same source, were more than fulfilled. Inasmuch as the direct observations proposed would clearly demand all my available time and strength, I naturally desired to secure the photographic impressions from my private resources; not only because all of the observatory's funds would be required for the regular work, but also that I might be justified in reserving the photographs for measurement and study at my subsequent leisure, and might remove them from the country without impropriety, should I desire. Consequently, I addressed to the government a formal application for leave to use the large telescope for this purpose, at such times as might not interfere with the regular work of the observatory, and this permission was at once accorded with great cordiality, and a full understanding of the case.

The endeavor to secure the requisite funds by private subscription met with the same fate as the similar one in 1865, in behalf of the expedition then proposed. Promises were secured for a portion of the necessary means, but the difficulty of obtaining the full sum was found too serious to warrant a continuance of the efforts, and the plan was therefore abandoned. But this disappointment was alleviated by an unexpected and delightful encouragement. My parents, by blood and marriage, gave a practical support and token of sympathy by authorizing me to draw on them for the means of carrying out my fondly cherished plan. And although I was fortunately able to go forward without availing myself of this generous permission, it was of essential service in the justification it afforded me in undertaking this work, upon which I might not otherwise have ventured.

That this undertaking has thus far been less successful than the rest of the work, many of you know; and I will not dwell upon the various troubles, mortifications, and disappointments which have attended my struggles in this direction. A photographer was engaged in New York by the friendly efforts of Mr. Rutherfurd, who caused him to be instructed in his observatory, and sent him out to me, with all the needful apparatus and chemicals. But when, after his arrival in Cordoba, I unpacked the photographic object-glass, the flint lens was found broken in two, and all efforts to restore it to full usefulness proved fruitless. Nevertheless, a contrivance was carried into effect by a skillful Swiss watchmaker in Cordoba, by means of which each of the broken pieces was supported by three pairs of adjusting screws, thus permitting it to be

brought into position with sufficient nicety to yield results which, if not perfect, will be at least very serviceable. Meanwhile, I resolved to avail myself of the opportunities at my disposal for procuring a new object-glass like the former, and sent the order to Mr. Fitz. But here, too, the Argentine government was ready with its support, and not only volunteered to assume the cost of the new lens, but expressed its desire to provide the services of the photographer. This new lens arrived in Cordoba many months ago, and although the person originally engaged accomplished but little, and proved in the end unworthy, my plan is by no means abandoned. The experience and knowledge already acquired cannot fail to render essential service in the new attempt, and the results of the Uranometry and the Zone-observations have enabled me to complete and correct the list of southern clusters well adapted for photographic determination. Meanwhile, the stellar photographs already secured, although by no means what I had hoped, and very disproportionate in number to the expense and sacrifices which they entailed, certainly possess a high scientific value. Repeated observations of the principal stars of each group have been made with the meridian-circle, for the purposes of fixing the scale of measurement, and of controlling the reductions; and I entertain the confident hope that the relative positions of more than a dozen important southern clusters have thus been secured in a form which is both very accurate, and as valuable for future generations as for the present.

I have spoken of the liberality of the Argentine government. In both its executive and legislative departments there are continual illustrations of the strong desire of the cultivated men of the nation to foster the intellectual development and the scientific reputation of the country by every means in their power. I have mentioned the readiness of the government to aid an astronomical expedition at the very time when all the nation's energies and resources were taxed to the utmost by the struggle with the Paraguayan despot, Lopez, one of the most sanguinary and ruthless tyrants in all history. At the time of my arrival in Buenos Ayres this monster had been overthrown by the allied forces of Brazil and La Plata, but internal rebellion, probably in part a consequence of that struggle, still remained, and pressed heavily upon the almost exhausted nation. Still there was not only ready support for the observatory, but additional provision was made for its maintenance. Thus it has been from the beginning to the present time, and the fact of such readiness in a young nation to bear its part in scientific investigation speaks for itself. Another illustration is afforded by the recently established meteorological office.

The climatic relations of the vast territory of the Argentine nation were a sealed book. Throughout the immense tract from the tropics to the Straits of Magellan, and from the Atlantic to the Andes, the meteorological characteristics of the country were almost unknown. Only two or three small series of partial observations had ever been published,

and these were not easily accessible. And although my powers were already taxed to their utmost by the astronomical work, it seemed to me that it would be disloyal alike to science and to the country to which I owe so much gratitude and affection, did I not make some effort to remedy this defect. In public communications and private conferences I called the attention of the government to the need of such a national meteorological office, and offered such aid as I could give. The meteorological office was thereupon established without opposition; funds being voted for the salary of a secretary, and for the purchase of instruments, to be distributed to such competent persons as might be willing to undertake systematic observations. This is the second year, and means have now been provided for computing and publishing the observations received, and for purchasing yet more instruments. There seem to be persons enough who are able and willing to undertake the necessary labor, troublesome as it is, and with no other stimulus than their desire to serve science and their country. In three cases I have found gentlemen who have carried on observations of the sort during past years, unaided and unencouraged. These have cordially offered all their data, gratified at seeing their labors appreciated at last, and their results put in the way of rendering service to science and the country. The transportation of delicate instruments in the interior is extremely difficult and hazardous. Outside the province of Buenos Ayres few railroads are yet completed, and notwithstanding the recent efforts of the government, there are as yet few roads over which a vehicle can safely pass for any considerable distance. But I am gradually succeeding in conveying mercurial barometers, thermometers of various sorts, rain-gauges, vanes, anemometers, &c., into remote regions, and the monthly reports have already begun to flow in from various quarters. The principal objects at first must be to interest and instruct observers, to provide them with facilities, and to collect and reduce all possible data, old and new, and subject them to careful study. Thus far I feel well satisfied with the interest already awakened, and I think that this young nation, so long struggling with foreign enemies and internal dissensions, has reason to be proud of the number, relatively large, even though intrinsically small, who are ready to work for her welfare and honor, without hope of personal glory or emolument. A few years will afford material for a knowledge of the climatic relations of various points; I shall then hope for simultaneous observations in numerous places, and who knows but the Argentine Republic may yet have an "Old Probabilities" of her own?

I cannot close this cursory but, I fear, tedious sketch of the results of my undertaking, without referring again to the extreme friendliness and kindness of the people. Not to dwell too much upon personal matters, let me say, once for all, that from no Argentine, high or low, have we had other experience than cordial hospitality, fraternal kindness, or respectful consideration. A heartier welcome, a sincerer sympathy in

weal or woe, we could hardly have expected in our own country. I am the more anxious to mention this, since I have seen paragraphs circulating in the public press to the effect that some of our instruments have been maliciously broken. If we should say "wantonly," the statement would be true to some extent; yet not because the apparatus was ours, but because its necessary exposure presents a tempting lure for some half-civilized gaucho, fortified with a full complement of alcohol, to try the accuracy of his aim. All races have their weak points, and our apparatus has fared far better than the new street-lanterns of Cordoba; nor would it be fair to expect from the unbreeched and untutored sons of the pampas, what I am assured could not be reasonably expected from the youth of some portions of the United States.

The fact that the thoughtful men and leaders of opinion in the Argentine Republic are awake to the educational and social needs of the people, furnishes in itself a guarantee that these needs will continue to be supplied. All the tendencies are toward progress. The vast territory of the nation possesses a population scarcely greater than that of Massachusetts, and three-fourths of this is a mixed progeny of the African negro, the South American Indian, and the Spanish peasant, in which it is difficult to say which element predominates. To a surpassing agility and dexterity in the arts of savage life they join all that sleepy indifference to improvement which the southern sun seems to engender in the lower classes. With not the slightest lack of what is called religion, they have a melancholy want of morality, and discriminate broadly between the two, which indeed they consider to have little to do with each other. Reading and writing are a rare accomplishment among this class, and not even pecuniary stimulus to labor is of much avail. Outside the cities, such elegances as pantaloons are rare, and various accessories which we consider absolute necessities of civilized life are unknown. Yet in constant intercourse with these people are others, their own countrymen, refined, accustomed to opulence, and desirous of contributing to the advancement of their native land. From this class come the legislators; and happy is that land whose lawgivers are taken from among the best educated and most patriotic! All the national energies not requisite for self-defense or self-preservation are now given to the development of the resources of the country, physical and moral. Our four years' observation has exhibited one continuous series of essential improvements. Railroads and telegraphs are springing into being with marvelous rapidity, spanning the before limitless pampas, and traversing the Andes. Roads, bridges, schools, and colleges have been almost doubled within my own experience. Mails are crossing the almost trackless prairies, steamboats are exploring the unnavigated rivers. And, more than all, these advances are not the mere policy of a single administration, enlightened as this policy has been; but they represent the spirit and determination of the ruling classes, which the result of no election can restrict, but in manifesta-

tions of which all parties vie. An impulse has been given to trade, new comforts have been introduced, and the habits and usages are growing more similar to those of other countries. In Cordoba, which the residents of other parts of the country love to ridicule as the special abode of bigotry and priestcraft, we have never suffered the smallest discourtesy for our difference of creed, but a frank and cordial treatment from clergy and laity alike. Buenos Ayres, like New York, is a cosmopolitan rather than a national city, and can just as little be said to represent the country of which it is the principal seaport. There we find the luxury, the vice, and the strange contrasts which a great capital always presents; but there, too, we find as earnest and enlightened a patriotism as any country can boast or desire. Both cities will be forever endeared to us by the memory of successful labors, of continual kindness, of cordial aid, and, lastly, of the most tender sympathy.

RECENT ESTIMATE OF THE POPULATION OF THE WORLD.

By Ed. Mailly.

[Translated from the French* for the Smithsonian Institution.]

Note.—The author has made all his calculations in square kilometers. They have been reduced by the translator to English square miles by the following formula: 1 square kilometer=.38614 square miles.

Attempts have been made at different periods to estimate the population of the world. Confining ourselves to recent times, in 1787 Büsching estimated the number to be 1,000,000,000. Until about fifteen years ago this number was still admitted as a base in arranging the population according to the different races, religious creeds, &c. In 1858, M. Dieterici stated the number to be 1,283,000,000; that is, not far from 1,300,000,000.† MM. Behm and Wagner, however, recently estimated the number at 1,377,000,000.‡

The difficulties of arriving at a correct estimate will readily be understood. The present regularly-organized systems of census do not include more than one-fourth of the human race, while the numbers of the remaining three-fourths have to be estimated from the reports of travelers; and in using this only resource we are very frequently puzzled, by obtaining contradictory results, from amid which nothing but careful criticism can obtain an approximation to truth.

The ideal of the statistician would be to have a census taken of the population on the same day and on the same general plan in all the inhabited parts of the world.

Probably this can only be attained at a future time, when people become naturally precise; still it should no longer be deemed chimerical.

A knowledge of the distribution of the population in the different parts of the globe, or over the different countries which compose these parts, has comparatively little value, unless accompanied by that of the area of these countries, in which case we may calculate the relation between the number of inhabitants and the surface of the territory over which they are distributed.

* L'Annuaire de l'Observatoire royal de Bruxelles, for 1873, p. 128.

† In the annual report of the observatory for the year 1859 was given an analysis of the memoir on the population of the earth, contributed by M. Dieterici to the Academy of Sciences of Berlin in March, 1858.

‡ Mittheilungen aus Justus Perthes' geographischer Anstalt, von Dr. A. Petermann, No. 33, 1872.

The measurement of the surface of the earth is also to a considerable degree uncertain; but it is much easier to approximate the truth in this particular than in the case of population. Large triangulations have been extended over considerable parts of the earth, while the form and the dimensions of continents, by the determinations of latitudes and longitudes, leave not much cause for doubt. After their value has been ascertained, by employing a uniform standard of measure, we are finally able to determine the superficies with a sufficient exactness.

In the following work we intend to give a general idea of the late researches of MM. Behm and Wagner, of which we previously made mention. The authors do not propose to present comparative numbers concerning the changes in the population of countries in which the census is taken periodically, but have endeavored to obtain the most probable actual number of the total population for each state from the latest determinations. The areas are given by MM. Behm and Wagner in German geographical square miles and in square kilometers, for the reductions of which the following formulas have been employed: 1 German geographical mile, or $\frac{1}{15}$ of a degree at the equator = 7420.43854 meters; 1 German geographical square mile = 55.0629081 square kilometers. We shall here give the areas in square miles; but we also give the number of inhabitants per square mile, an element which our authors have not calculated, but have reserved for another publication. In order to facilitate the comparison of the different states of Europe, we add the proportional numbers relating to population and to the area of the states, separately considered.

Population of the earth.

Parts of the globe.	Square miles.*	Population.*	Inhabitants per square mile.
I. Europe	3, 787, 400	301, 605, 000	79. 63
II. Asia	16, 924, 600	794, 000, 000	46. 97
III. Australia and Polynesia	3, 425, 400	4, 365, 000	1. 27
IV. Africa	11, 557, 400	192, 520, 000	16. 66
V. America	15, 987, 000	84, 524, 000	5. 29
Total*	51, 681, 800	1, 377, 014, 000	26. 64

*In round numbers.

It must be borne in mind that the numbers in the fourth column represent only ratios; but if we should desire to reject fractions of inhabitants, it would become necessary to give the number per square league, and to obtain this it would be sufficient to multiply the numbers of the fourth column by 9. The result of this operation would be 717, 423, 11, 150, and 48, respectively, per square league, in Europe, Asia, Australia, Africa, and America. For the earth, the number would be 240. We might also consider the number of inhabitants per 100 square miles, and then the decimals would disappear entirely, giving the results 7,963, 4,697, 127, 1,666, and 529; and by multiplying these numbers by .9, we would re-produce those which represent the number of inhabitants per square league.

I.—EUROPE.

Countries.	Square miles.	Population.	Inhabitants per square mile.	Proportions. Area.	Proportions. Population.
German empire	208, 632	41, 058, 139	196. 80	5. 51	13. 61
Austro-Hungary	240, 363	35, 904, 435	149. 38	6. 35	11. 91
Principality of Lichtenstein	62	8, 320	134. 20	....	....
Switzerland	15, 993	2, 669, 147	166. 90	0. 42	0. 89
Denmark	14, 754	1, 784, 741	120. 97	0. 39	0. 59
Faroe Islands and Iceland	40, 269	79, 755	1. 98	1. 06	0. 03
Sweden and Norway	292, 891	5, 921, 525	20. 22	7. 73	1. 96
Netherlands	12, 681	3, 688, 337	290. 85	0. 33	1. 22
Grand Duchy of Luxemburg	999	197, 504	197. 00	0. 03	0. 07
Belgium	11, 374	5, 021, 336	441. 47	0. 30	1. 67
Great Britain and Ireland	121, 122	31, 817, 108	262. 68	3. 20	10. 55
Helgoland, Gibraltar, and Malta	145	160, 369	1, 106. 00	....	0. 05
France	204, 104	36, 469, 836	178. 68	5. 39	12. 09
Spain	192, 978	16, 374, 844	84. 86	5. 10	5. 43
Canary Islands	2, 808	267, 036	95. 10	0. 07	0. 09
Portugal	34, 504	3, 995, 153	115. 80	0. 91	1. 32
Azores and Madeira	1, 311	365, 821	279. 04	0. 05	0. 12
Republic of Andorra	149	12, 000	80. 54	....	....
Italy	114, 302	26, 716, 809	233. 74	3. 02	8. 86
Principality of Monaco	6	3, 127	521. 00	....	....
Republic of San Marino	22	7, 303	332. 00	....	....
Turkey in Europe	134, 003	10, 510, 000	78. 43	3. 54	3. 49
Roumania	46, 713	4, 500, 000	96. 33	1. 25	1. 49
Servia	16, 818	1, 319, 283	78. 45	0. 44	0. 44
Montenegro	1, 701	100, 000	58. 79	0. 05	0. 03
Russia	2, 059, 355	71, 195, 405	34. 57	54. 35	23. 61
Greece	19, 354	1, 457, 894	75. 33	0. 51	0. 48
Total	3, 787, 413	301, 605, 227	79. 63	100. 00	100. 00

On a mere glance at the foregoing table we are astonished at the greatness of the Russian empire; it occupies more than half of Europe. Arranged in the order of their size, there follow Sweden and Norway, Austro-Hungary, the German empire, France, Spain, Turkey, Great Britain and Ireland, and Italy, all of which together do not comprise four-tenths of the surface.

Ranged according to population, the above-named states will appear in the following order: Russia, Germany, France, Austro-Hungary, Great Britain and Ireland, Italy, Spain, Turkey, Sweden and Norway. Russia retains the first place, but the kingdom of Sweden and Norway ranks with the small countries; it is the least densely populated country in Europe, as is evident by examining the column of the preceding table, headed "Inhabitants per square mile."

Passing over the very small countries whose population does not reach one million, and which would furnish but illusory or exceptional results,* we remark that there are two second-rate countries which rank in this particular with the great powers, namely, Belgium and the Netherlands, which have the greatest number of inhabitants per square mile, that is, in the language of statisticians, have the densest population. They are followed by Great Britain and Ireland, Italy, Germany, France,

* Thus it is evident that we would not place in the front rank Helgoland, Gibraltar, and Malta, on one hand, and Monaco, on the other, the densities of whose populations reach the following numbers: 427.65 and 208.46 per square kilometer, or 1,106 and 521 per square mile.

Switzerland, Austria, Denmark, Portugal, Roumania, Spain, Turkey, Servia, Greece, Russia, and Sweden and Norway, the two largest countries of Europe being reduced to the lowest grade in regard to the density of the population.

We shall now consider some of the great countries of Europe in detail.

The following table shows the states which, combined, form the German empire:

(*a.*)—GERMAN EMPIRE.

States.	Square miles.	Population.	Inhabitants per square mile.
Kingdoms of—			
Prussia, including Lauenburg	134, 396	24, 691, 203	183. 72
Bavaria	29, 294	4, 861, 402	165. 95
Saxony	5, 780	2, 556, 244	442. 26
Würtemberg	7, 533	1, 818, 484	241. 42
Total	177, 003	33, 927, 333	191. 70
Grand duchies	18, 942	3, 571, 974	188. 57
Duchies	4, 549	1, 019, 414	224. 10
Principalities	2, 174	476, 262	219. 08
Free towns	368	513, 697	1, 395. 91
Elsass-Lothringen	5, 596	1, 549, 459	276. 90

The above table shows that, among the kingdoms which compose the German empire, Saxony is the most important in point of density of population, the number of inhabitants per square mile even exceeding that of Belgium.

The grand duchies are six in number, namely: Baden, Hessen, Mecklenburg-Schwerin, Saxe-Weimar, Mecklenburg-Strelitz, and Oldenburg. The largest population is found in Baden, (1,461,428;) but it is most dense in Hessen, amounting to 111.10 per square kilometer, or 287.61 per square mile, while in Mecklenburg-Strelitz it is represented by the number 35.59 per square kilometer, or 92.17 per square mile.

The duchies are five in number, namely: Brunswick, Saxe-Meiningen, Saxe-Altenburg, Saxe-Coburg-Gotha, and Anhalt, and the density of their population is much more uniform than that of the grand duchies; Saxe-Altenburg, however, excelling, having 107 per square kilometer, or 278.53 per square mile.

The number of principalities is seven, namely: Schwarzburg-Rudolstadt, Schwarzburg-Sondershausen, Waldeck, Reuss, (senior branch,) Reuss, (junior branch,) Schaumburg-Lippe, and Lippe-Detmold, and their combined population does not reach half a million. The least dense population is found in the largest of these principalities, Waldeck, being 50.14 per square kilometer, or 130 per square mile; while in the much smaller Reuss (senior branch) it numbers 164.12 per square kilometer, or 425 per square mile, thus showing a density of three times that of Waldeck.

The free towns are Lubeck, Bremen, and Hamburg. In these the density is very considerable, amounting in Hamburg to 827.21 per square kilometer, or 2,142.25 per square mile.

(*b.*)—AUSTRO-HUNGARY.

States.	Square miles.	Population.	Inhabitants per square mile.
Austria	115, 916	20, 394, 980	175. 95
Hungary	124, 447	15, 509, 455	124. 63

Austria consists of fourteen states, of which the most densely-populated are Austria proper, Styria, Bohemia, Moravia, and Galicia; Hungary includes Hungary proper, Transylvania, Croatia, and Slavonia, the Military Frontier, and the free town of Fiume.

(*c.*)—GREAT BRITAIN AND IRELAND.

States.	Square miles.	Population.	Inhabitants per square mile.
Great Britain:			
England	50, 926	21, 487, 688	421. 94
Wales	7, 398	1, 216, 420	164. 42
Scotland	30, 688	3, 358, 613	109. 44
Islands	354	144, 439	408. 00
Ireland	31, 756	5, 402, 759	170. 13
Sailors out of the country	....	207, 198	....

The foregoing table plainly shows that the density of population per square mile in England nearly equals that of Wales, Scotland, and Ireland combined.

II.—ASIA.

Countries.	Square miles.	Population.	Inhabitants per square mile.	Proportions. Area.	Proportions. Population.
Russia in Asia	5, 944, 962	10, 730, 000	1. 81	35. 56	1. 35
Turkey in Asia	672, 559	16, 463, 000	24. 48	4. 02	2. 07
Arabia	1, 026, 104	4, 000, 000	3. 90	6. 14	0. 50
Persia	636, 000	5, 000, 000	7. 86	3. 80	0. 03
Afghanistan, including Herat	251, 180	4, 000, 000	15. 92	1. 50	0. 50
Beloochistan	106, 774	2, 000, 000	18. 73	0. 64	0. 25
Kafiristan	19, 958	300, 000 ?	15. 00	0. 12	0. 04
Khiva	54, 208	1, 500, 000	27. 67	0. 33	0. 19
Bokhara	76, 305	2, 500, 000	32. 75	0. 46	0. 32
Khokhan	30, 020	800, 000	26. 65	0. 18	0. 10
Turcomania	144, 189	770, 000	5. 34	0. 86	0. 10
Other khans and territories of Touron	134, 550	2, 000, 000 ?	14. 87	0. 81	0. 25
Turkestan	595, 428	580, 000	0. 97	3. 56	0. 07
China	3, 742, 083	446, 500, 000	119. 32	22. 38	56. 22
Japan	149, 408	34, 785, 321 ?	232. 82	0. 89	4. 38
Hither India	1, 558, 845	206, 225, 580	132. 29	9. 32	25. 97
Ceylon	24, 706	2, 405, 287	97. 36	0. 15	0. 30
Farther India	752, 131	21, 018, 062	27. 94	4. 50	2. 65
Indian Archipelago	799, 408	32, 620, 000	40. 80	4. 78	4. 11
Total	16, 718, 818	794, 197, 250	*47. 53	100. 00	100. 00
Caspian Sea	178, 882				
Sea of Aral	26, 947				
Total	16, 924, 647				

* This number differs a little from the one (46.97) given in the first table, in which the Caspian Sea and the Sea of Aral were included in the area of Asia.

From the above we see that the Russian empire, covering more than half of the European continent, occupies also about three-eighths of the surface of Asia. China does not extend over much more than two-tenths of the total surface; but, in the arrangement according to population, it is entitled to the first place, followed by British India, Japan, and the Indian Archipelago; these added together, include nine-tenths of the entire population, while their total surface does not cover much more ground than Russia in Asia.

In point of density Japan excels, nearly equaling the Italian kingdom. Next, but at a considerable distance, follow English India, China, and the island of Ceylon. The density of the Chinese empire nearly equals that of Denmark.

We shall now examine more in detail some of the states presented in the foregoing general table.

(*a*.)—RUSSIA IN ASIA.

States.	Square miles.	Population.*	Inhabitants per square mile.
Caucasus	169, 641	4, 661, 824	27. 48
Siberia	4, 718, 283	3, 327, 627	0. 75
Central Asia	1, 057, 038	2, 740, 583	2. 59

* The total is 10,730,034, while in the general table the round number, 10,730,000, has been given.

(*b*.)—HITHER INDIA, INCLUDING BURMAH.

States.	Square miles	Population.	Inhabitants per square mile.
English India	910, 909	159, 666, 428	175. 28
French possessions, (Pondicherry and Chandernagore)	196	259, 981	1, 326. 43
Portuguese possessions, (Goa, Damaun, and Diu)	1, 553	53, 283	34. 31
Independent States	646, 187	46, 245, 888	71. 56

The extraordinary density of population in the French possessions is explained by the fact that these possessions are reduced to the cities of Pondicherry and Chandernagore. The area of the territories belonging to England is only double that of the more or less independent states, but the population is about three and one-half times as large.

(*c*.)—FARTHER INDIA.

States.	Square miles.	Population.	Inhabitants per square mile.
Burman Empire	190, 529	4, 000, 000	21. 00
Siam	309, 043	6, 298, 000	20. 38
Anam	198, 055	9, 000, 000	45. 44
Cochin-China, French	21, 718	1, 204, 287	55. 45
District of Malacca	1, 084	306, 775	283. 00
Peninsula of Malacca	31, 702	209, 000	6. 58

The relatively large density of population of the English establishments in the district of Malacca is due to the nature of those establishments, which contain two important cities. Their populations are, Singapore, 97,131; Malacca, 77,755; Penang and Wellesley, 131,889.

(d.)—EAST INDIAN ARCHIPELAGO.

States.	Square miles.	Population.	Inhabitants per square mile.
Islands of Sunda and Molucca	678, 512	25, 000, 000	36. 84
Philippines and island of Sooloo	114, 134	7, 450, 000	65. 28
Groups of islands, (Laccadives, Maldives, &c.)	6, 761	170, 000	25. 14

The Dutch possessions in the Sunda Islands and in the Moluccas have 23,337,829 inhabitants; the Spanish possessions in the Philippines, 4,319,269.

III.—AUSTRALIA AND POLYNESIA.

Countries.	Square miles.	Population.	Inhabitants per square mile.
Australian Continent	2, 945, 409	1, 565, 294	0. 53
Islands	480, 011	2, 800, 000	5. 83
Total	3, 425, 420	4, 365, 294	1. 27

(a.)—AUSTRALIAN CONTINENT.

States.	Square miles.	Population.	Inhabitants per square mile.
New South Wales	308, 579	501, 580	1. 62
Victoria	88, 456	729, 868	8. 25
South Australia	380, 626	188, 995	0 50
Queen's Land	668, 300	120, 066	0. 18
West Australia	975, 884	24, 785	0. 02
Territory of the North	523, 563	....	....

(b.)—POLYNESIAN ISLANDS.

States.	Square miles.	Population.	Inhabitants per square mile.
Tasmania	26, 217	99, 328	3. 79
New Zealand	106, 266	294, 028	2. 77
Islands belonging to France or under French protection	11, 098	78, 000	7. 03
New Guinea	274, 535	1, 000, 000	3. 64
Sandwich Islands	7, 633	62, 959	8. 25
Spanish possessions, (Caroline, Palao, and Mariana Islands)	1, 333	33, 610	25. 21
Other islands	52, 929 ?	1, 232, 075	23. 28

IV.—AFRICA.

States.	Square miles.	Population.	Inhabitants per square mile.	Proportions.	
				Area.	Population.
North Africa	4, 004, 000*	20, 420, 000*	5. 1	37. 17	10. 61
Mohammedan empire of Middle Soudan	631, 096	38, 800, 000	61. 48	5. 86	20. 15
West Soudan †	818, 617	38, 500, 000	47. 03	7. 60	20. 00
East Africa	1, 594, 758	29, 700, 000	18. 62	14. 80	15. 43
South Africa	1, 966, 032	16, 000, 000	8. 14	18. 25	8. 31
Equatorial territory	1, 522, 356	43, 000, 000	28. 24	14. 13	22. 33
Islands in the Atlantic	2, 723	99, 145	36. 41	0. 02	0. 05
Islands in the Indian Ocean	233, 885	6, 000, 000	25. 65	2. 17	3. 12
Total	10, 773, 440‡	192, 519, 145	....	100. 00	100. 00

* Round numbers.

† From the Senegal to the Lower Niger, including Upper Guinea.

‡ The difference between this number and the one given in the general table of the world is due to the fact that this table of the principal divisions of Africa does not include the interior lakes, the desert of Kalahari, &c.

From the above table we learn that the northern and southern portions of Africa, whose territories are proportionally the greatest, have the least population. Middle Soudan, West Soudan, and the equatorial region, which, combined, occupy only half as much surface, have a population three and one-third times greater, which is the densest in Middle Soudan.

(*a.*)—NORTH AFRICA.

States.	Square miles.	Population.	Inhabitants per square mile.
Morocco	259, 601	2, 750, 000	10. 59
Algeria	258, 328	2, 921, 146	11. 31
Tunis	45, 719	2, 000, 000	43. 74
Tripoli, with Barca and Fezzan	344, 437	750, 000	2. 18
Egypt	659, 141	8, 000, 000	12. 14
Sahara	2, 436, 621	4, 000, 000	1. 64

The density of the population is about the same in Morocco, Algeria, and Egypt, while that of Tunis is about four times as great.

(*b.*)—WEST SOUDAN.

States.	Square miles.	Population.	Inhabitants per square mile.
Senegambia, (French)*	96, 535	209, 162	2. 17
Liberia †	9, 576	718, 000	74. 98
Dahomey	3, 985	180, 000	45. 17
English possessions ‡	17, 116	577, 313	33. 73
Portuguese possessions §	35, 880	8, 500	0. 24

* Senegal and dependencies.

† American colony, founded in 1821, in Upper Guinea.

‡ Sierra Leone, colony founded in 1787, Gambia, Cote d'Or, Upper Guinea, and Lagos.

§ In Senegambia and Guinea.

(c.)—EAST AFRICA.

States.	Square miles.	Population.	Inhabitants per square mile.
Abyssinia	158, 395	3, 000, 000	19. 00

(d.)—SOUTH AFRICA.

States.	Square miles.	Population.	Inhabitants per square mile.
Portuguese territory, (on the east side) *	382, 279	300, 000	0. 78
Portuguese territory, (on the west side) †	312, 542	9, 000, 000	22. 39
Colony of Cape of Good Hope	221, 325	682, 600	3. 08
Natal	17, 803	269, 362	15. 13
Free State of Orange River	42, 475	37, 000	0. 87
Republic of Transvaal	114, 365	120, 000	1. 05

* Mozambique, Sofala, &c. † Angola, Benguela, Mossamedes.

(e.)—ISLANDS IN THE ATLANTIC OCEAN.

States.	Square miles.	Population.	Inhabitants per square mile.
Island of Cape Verde*	1, 650	67, 347	40. 81
Islands of Saint Thomas and Prince*	454	19, 295	42. 50
Islands of Fernando Po and Annobon †	489	5, 590	11. 43
Ascension Island	38	....	....
Island of Saint Helena ‡	47?	6, 860	145. 94
Tristan d'Acunha	45	53	1. 18

* To Portugal. † To Spain. ‡ To England.

(f.)—ISLANDS IN THE INDIAN OCEAN.

States.	Square miles.	Population.	Inhabitants per square mile.
Socotra	1, 701	3, 000	1. 76
Abd-el-Curia	64	100	1. 56
Zanzibar	617	380, 000	615. 89
Madagascar	228, 588	5, 000, 000	21. 87
Comoro Isles, (with Mayotto)	1, 062	64, 600	60. 83
The Arco Islands, &c	149	....	....
Reunion Island *	970	209, 737	216. 22
Maurice and dependencies †	708	322, 924	456. 11

* To France. † To England.

V.—AMERICA.

States.	Square miles.	Population.	Inhabitants per square mile.	Proportions. Area.	Proportions. Population.
North America	8, 658, 122	51, 964, 000	6. 00	54. 46	61. 48
Central America	188, 387	2, 671, 000	14. 18	1. 19	3. 16
West Indies	91, 664	4, 214, 000	45. 97	0. 58	4. 99
South America	6, 959, 015	25, 675, 000	3. 69	43. 77	30. 37
Total	15, 897, 188	84, 524, 000	5. 31	100. 00	100. 00

(a.)—NORTH AMERICA.

States.	Square miles.	Population.	Inhabitants per square mile.	Proportions. Area.	Proportions. Population.
Greenland*	759, 861	10, 000	....	8. 78	0. 02
British possessions†	3, 524, 370	3, 888, 557	1. 10	40. 71	7. 48
Bermudas‡	24	11, 796	....	....	0. 02
St. Pierre and Miquelon	81	3, 971	....	....	0. 01
United States	3, 612, 068	38, 877, 000	10. 76	41. 72	74. 82
Mexico	761, 718	9, 175, 052	12. 04	8. 79	17. 65

* To Denmark.
† Comprising Canada, Newfoundland, and Prince Edward Island.
‡ To England.

(b.)—CENTRAL AMERICA.

States.	Square miles.	Population.	Inhabitants per square mile.	Proportions. Area.	Proportions. Population.
Republic of Guatemala	40, 781	1, 180, 000	28. 93	21. 65	44. 19
Republic of San Salvador	7, 336	600, 000	81. 79	3. 89	22. 47
Republic of Honduras	47, 095	350, 000	7. 43	25. 00	13. 10
Republic of Nicaragua	58, 174	350, 000	6. 01	30. 88	13. 10
Republic of Costa Rica	21, 496	165, 000	7. 67	11. 41	6. 18
British Honduras	13, 501	25, 635	1. 90	7. 17	0. 96

(c.)—WEST INDIES.

States.	Square miles.	Population.	Inhabitants per square mile.	Proportions. Area.	Proportions. Population.
Spanish possessions*	49, 483	2, 068, 870	41. 81	53. 98	49. 10
English possessions†	12, 636	1, 054, 116	83. 42	13. 79	25. 01
French possessions‡	1, 017	306, 244	301. 12	1. 11	7. 27
Dutch possessions	368	35, 482	....	0. 40	0. 84
Danish possessions	119	37, 821	....	0. 13	0. 90
Swedish possessions	8	2, 898	....	0. 01	0. 07
Republic of Hayti	10, 206	572, 000	56. 04	11. 13	13. 57
Republic of San Domingo	17, 828	136, 500	7. 66	19. 45	3. 24

* Cuba and Porto Rico.
† Jamaica, Barbadoes, Tabago, Trinidad, &c.
‡ Martinique and Guadaloupe and dependencies.

(*d.*)—SOUTH AMERICA.

States.	Square miles.	Population.	Inhabitants per square mile.	Proportions.	
				Area.	Population.
Brazil	3, 253, 230	10, 000, 000	3. 07	46. 74	38. 95
French Guiana	35, 081	25, 151	0. 71	0. 50	0. 10
Dutch Guiana	59, 802	59, 885	1. 00	0. 86	0. 23
British Guiana	99, 933	152, 932	1. 53	1. 43	0. 60
Venezuela	368, 262	1, 500, 000	4. 08	5. 29	5. 84
United States of Colombia	357, 180	3, 000, 000	8. 40	5. 13	11. 69
Ecuador	218, 941	1, 300, 000	5. 94	3. 15	5. 06
Gallapagos Islands	2, 954	....	....	0. 04	....
Peru	510, 477	2, 500, 000	4. 90	7. 33	9. 74
Bolivia	535, 962	2, 000, 000	3. 73	7. 70	7. 79
Chili	132, 624	2, 000, 000	15. 08	1. 91	7. 79
Argentine Confederation	871, 904	1, 812, 000	2. 08	12. 53	7. 06
Patagonia and Terra del Fuega	376, 487	24, 000	....	5. 41	0. 09
Paraguay	63, 790	1, 000, 000 ?	15. 67	0. 92	3. 89
Uruguay	66, 725	300, 000	4. 50	0. 96	1. 17
Falkland Islands	4, 741	686	....	0. 07	....
Aurora Island and Georgia	1, 786	....	....	0. 03	....

In examining the above tables one will at once be astonished at the disproportion between the population of North and South America. While their areas are in the proportion of 10 to 8, their populations are in the proportion of but 10 to 4.9.

The population of the United States forms nearly three-fourths of the North American and nearly one-half of the entire American population. Though its area is about the same as that of the British possessions, it has nearly ten times the population.

While the area of Mexico and that of Greenland are the same, their populations differ in the proportion of 917 to 1.

Among the small republics in Central America, Guatemala has the largest population; but, in regard to density, San Salvador excels. They all combined have a much denser population than the United States and Mexico.

In the West Indies the Spanish possessions occupy the first place, not in regard to extent, but to population. But, with an area of about one-fourth that of the former, the English possessions have a population of more than half their number; that is to say, twice the density. The density of population in the French possessions is still greater, attaining the number of 116 per square kilometer, or 300 per square mile.

Brazil occupies the first place in South America. Its territory extends over nearly as much ground as that of the United States or of the British possessions in North America, but its population, though a little denser than that of the latter, is much less than that of the former country.

The greatest density is found in Paraguay and in Chili, approaching that of the kingdom of Sweden and Norway in Europe.

ON WARMING AND VENTILATING OCCUPIED BUILDINGS.

By Arthur Morin,
Director of the Conservatory of Arts and Trades, Paris.

[Translated for the Smithsonian Institution by Clarence B. Young.]

[General Morin, the author of this manual, has long been known as one of the most distinguished technologists of the French Academy. The translation and publication of his work on warming and ventilation will doubtless be considered a valuable addition to the English bibliography of the subject.—J. H.]

1. The means for producing warmth and ventilation are so closely connected, especially during the cold season, that it is almost impossible to treat them separately, even in such a review of the teachings of science and experiment as the present, and hence both these subjects have been included in the title.

WARMING.

GENERAL CONSIDERATIONS.

2. *Heating-apparatus.*—We may consider forms of heating-apparatus in three different respects:

1. In regard to economy of fuel.
2. In regard to effect on health.
3. In regard to comfort.

For heating places occupied but for short periods, such as the vestibules of public buildings, stairways, waiting-rooms, and even churches, the first of these considerations should decide the choice of apparatus.

For occupied buildings, however, the second consideration should have more weight; and here we may give as a rule that *every heating-apparatus or system of heating which does not provide in itself for an ample and regular change of air, or which is not connected with suitable arrangements for producing such a change, is injurious to health.*

In regard to the third consideration, while it is often opposed to the first, it is closely connected with the second, since there can be no method of producing pleasant warmth but such as is also healthful.

In the rapid review of heating-apparatus which we shall make under these three heads we shall distinguish between those used for special purposes and those for general heating.

OPEN FIRE-PLACES.

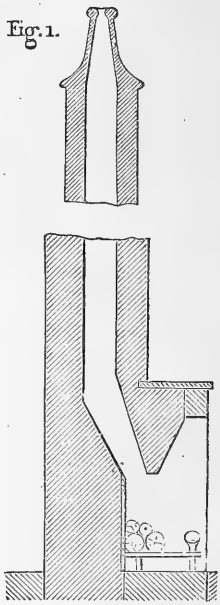
3. At the head of comfortable and healthful forms of heating-apparatus used within buildings are placed open fire-places, of which two different kinds may be distinguished:

1. Ordinary fire-places.
2. Ventilating fire-places.

The remarks which will be made in regard to the first, and the proportions suitable for them, will also apply to the second, which, indeed only differ by having some special arrangements.

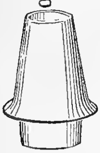
COMMON FIRE-PLACES.

Fig. 1.



Two distinct types may be considered. The first, which is the one most frequently met with, consists of a chimney of proper size, connected with the hearth at the bottom by means of a more or less narrow opening, the lower part of which forms the passage which Rumford called the throat of the chimney, (Fig. 1.) On the upper part of the flue is placed a sort of ajutage, called a chimney-shaft when built of bricks or tiles, and chimney-cap when made of terra-cotta, (Fig. 2.) The opening for the escape of the smoke is much smaller than the sectional area of the main flue. This type is almost the same as that devised by Rumford, and which bears his name; but while he pointed out its advantages over the old forms of chimneys in regard to draught, he did not determine the correct proportions of the several parts.

Fig. 2.



In the second type, often met with in the upper stories of houses in Paris, the flue, which is usually cylindrical, has the same sectional area throughout. It has been recommended by M. Peclet, in his treatise on heat, as proper for every case; but its use should be restricted to very small chimneys, and, in general, to cases where stoves are used for heating.

4. *General advantages and disadvantages of ordinary fire-places.*—Ordinary fire-places, which cause the removal of a considerable amount of air, and, therefore, the change of that in the apartments, present the incontestable advantage of forming a healthful mode of heating. But the air which is removed must necessarily be replaced by the external air, entering usually through the loose joints of the doors and windows, thus causing currents of cold air, which become more unpleasant the greater the size of the chimney or the stronger the draught produced by the fire. Consequently, as Rumford says, "the draughts chill one part of the body, while the rest is roasted by the fire in the fire-place, and this cannot but be injurious to health." All have noticed these effects

near a large fire-place in which a strong fire is burning. It is especially in the large rooms of country-houses that these effects are most apparent and unpleasant.*

In other and frequent cases—especially in Paris, owing to the confined kitchens, the proximity of water-closets, and the application of weather-strips to the joints of doors and windows—the draught of a chimney in which a strong fire is burning is supplied in part by the air which has passed through those places, thus introducing into the living-rooms unpleasant and unwholesome odors.

5. *Heating-effect of ordinary fire-places.*—The hot air from the fire passes out of the chimney at a temperature often at 140°, 175°, 212°, or more. It carries with it and diffuses in space, without useful effect, the greater part of the heat given out by the fuel.† This loss is as great as six-sevenths, seven-eighths, and more, of the heat produced, so that what can be called the heating-effect of an ordinary fire-place scarcely exceeds 12 or 14 per cent. of the total amount of heat produced by the fuel. It is necessary then, while retaining the advantage of a quick change of air, to restrict the amount and the temperature of the escaping air to that necessary to maintain the healthful condition of the room and the force of the draught.

6. *Proportions necessary to secure change of air and draught.*—A common chimney of the proportions usually adopted at present in Paris removes in an hour on an average an amount which equals and often exceeds five times the capacity of the room it is intended to warm, and this change of air will be sufficient in rooms of the usual size to secure a ventilation of over 1,000 cubic feet of air an hour for each person, supposing there be more than one for every 10 square feet of floor-room.

Again, in order that the draught should be sufficiently strong and unaffected by the wind, it is only necessary that the products of combustion should escape with a velocity of 10 feet a second in the case of a fire of average intensity; but it is unnecessary, and even injurious, to have so great a velocity in the main flue, where it should be only from 3 to 7 feet in a second, which is secured by making the flue sufficiently large.

The theoretical discussion of the conditions of the motion of air in chimneys, and the results of experiment, lead to the following rules for the proper proportions for chimneys in dwelling-houses.†

7. *Proportions of flues and shafts for private houses.*—For dwelling-houses in the city or in the country, only a few stories high, where the walls that the flues are built in are of sufficient thickness, the chimneys may be made of common bricks, and then the proper dimensions for the flues as well as for the shafts at the top, according to the size of the room, may be determined by the table given on the next page.

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* Essais politiques, économiques et philosophiques du comte de Rumford, t, 1er, p. 31.
† Études sur la ventilation, tome 1er, chap. 5, pp. 295 et suivants.

It may be remarked that the dimensions of flues given for rooms with an area of 10,000 cubic feet are quite large, and that it would be difficult to exceed them without causing the great annoyance which is experienced in large flues, that of causing descending currents of smoke when the fire is kindled.

It will, therefore, be better in warming such large rooms to use a heater in addition to the fire-place.

Area of room.	Volume of air to be changed every hour.	Flues.				Shafts.			
		Sectional area.	Rectangular.		Cylindrical diameter.	Sectional area.	Rectangular.		Cylindrical diameter.
			Length.	Breadth.			Length.	Breadth.	
Cubic ft.	*Cubic ft.*	*Sq. in.*	*Ft. In.*	*Ft. In.*	*Ft. In.*	*Sq. in.*	*Ft. In.*	*In.*	*Ft. In.*
3, 532	17, 658	144	1. 2, 9-16	0. 9, 13-16	0. 11, 1-2	72	1. 1	5, 1-2	0. 7, 1-2
4, 226	21, 189	172	1. 2, 9-16	0. 11, 13-16	0. 11, 3-16	86	1. 2, 9-16	5, 7-8	0. 8, 1-4
5, 296	26, 487	213	1. 6, 1-8	0. 11, 13-16	1. 1	108	1. 1, 11-16	8	0. 9, 7-8
6, 356	31, 784	258	1. 9, 5-8	0. 11, 13-16	1. 2, 1-2	129	1. 4, 1-8	8	0. 10, 3-16
7, 769	38, 847	316	1. 10, 13-16	1. 1, 11-16	1. 3, 3-4	158	1. 7, 11-16	8	0. 11, 3-16
10, 382	45, 910	373	1. 11, 13-16	1. 3, 3-4	1. 5, 5-16	186	1. 11, 5-8	8	1. 0, 3-16
10, 595	52, 973	430	2. 2	1. 3, 3-4	1. 6, 1-2	215	1. 11, 5-8	9	1. 1

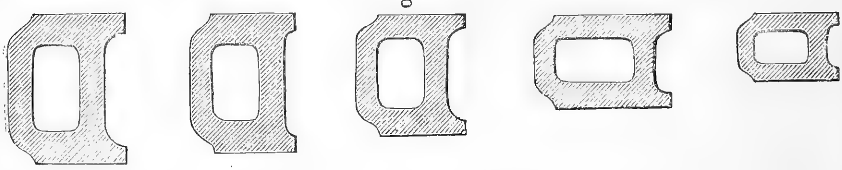
8. *Proportions of flues and chimney-caps in apartment-houses of many floors.*—In cities where houses are built of many stories to rent in flats, especially in Paris, chimneys are built of bricks of special forms or of pottery-ware pipes, on the top being usually placed cylindrical caps of the following dimensions:

Number of the pattern.	Diameter.	Sectional area.
	Inches.	*Sq. in.*
1	9, 13-16	76
2	8, 11-16	59
3	7, 1-2	44
4	6, 5-16	31

Three types of pottery-ware pipes may be distinguished:

9. *First type, pipes made in sections called wagons.*—(Fig. 3.)—They

Fig. 3.



are placed in the thickness of the partition-walls or in the face of the wall and forming part of it. Of these there are five different patterns or numbers, the proper one to be used depending upon the size of the rooms to be warmed and the thickness of the walls in which they are to be placed.

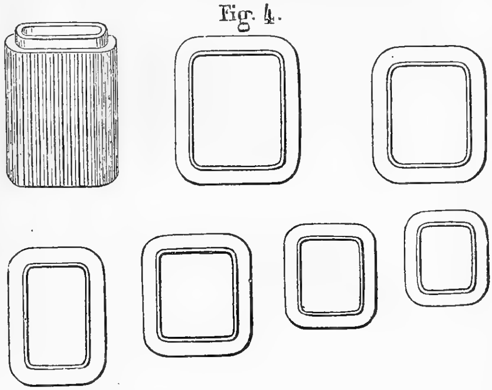
The number of the pattern of pipe and cap to be used may be determined by the following table:

Table of wagon-shaped pipes and caps to be used according to the thickness of walls and the size of rooms.

Capacity of room.	Thickness of walls.	Number of pattern.	Internal dimensions. Length.	Internal dimensions. Breadth.	Sectional area of flue, A.	Number of corresponding cap.	Sectional area of cap, A'.	Ratio of areas, A/A'.
Cubic feet.	*Ft. In.*		*Ft. In.*	*Ft. In.*	*Sq. in.*		*Sq. in.*	
3, 532–4, 944	1. 7, 11-16	1	1. 1, 1-4	0. 8, 1-4	111	1	76	1. 45
2, 825–3, 532	1. 4, 1-2	2	0. 11	0. 8, 1-4	91	2	59	1. 54
2, 825–3, 532	1. 3, 3-4	3	0. 10, 3-16	0. 8. 1-4	85	2	59	1. 43
2, 825–3, 532	1. 1, 3-8	4	0. 10, 5-8	0. 8, 1-4	88	2	59	1. 49
1, 589–2, 119	0. 9, 13-16	5	0. 7, 7-8	0. 7, 1-16	51	4	31	1. 78
								1. 54

10. *Second type, pipes made in sections called measures, designed for chimneys which project from the wall against which they are built.*—(Fig. 4.)—

Fig. 4.



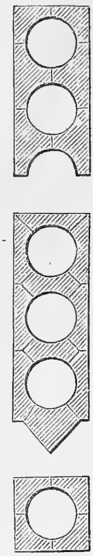
These pottery pipes are thin and have a mean height of 1 foot 9 inches. They are made in six numbers, which may be selected by the particulars given in the following table:

Dimensions of pipes made in the shape of measures and of the corresponding caps to be used according to the size of the place to be warmed.

Size of place to be warmed.	Number of pipe.	Internal dimensions. Length.	Internal dimensions. Breadth.	Area of flue. A	Number of corresponding cap.	Sectional area of passage, A'	Ratio, A/A'
Cubic feet.		*Inches.*	*Inches.*	*Sq. inches.*		*Sq. inches.*	
3, 532–4, 944	1	11, 13-16	9, 13-16	116	1	62	1. 53
2, 825–3, 532	2	9, 13-16	8, 11-16	85	2	59	1. 44
2, 119–2, 825	3	9, 13-16	6, 5-16	62	3	44	1. 42
2, 119–2, 825	4	8, 11-16	7, 1-2	65	3	44	1. 48
1, 589–2, 119	5	7, 1-2	6, 11-16	51	4	31	1. 62
....	6	6, 5-16	5, 1-8	32	....	....	1. 50

11. *Observation.*—It will be seen that these pottery flues are only suitable for rooms of ordinary size, and would be entirely insufficient for large reception-rooms.

Fig. 5.



12. *Third type, arch-shaped pipes called Gourlier's.*—(Fig. 5.)—This form of pipe is only employed for small chimneys or where stoves are used. The sections are molded in the form of voussoirs, and four are joined together to form the flue. Their thickness is usually $2\frac{3}{4}$ inches. There are only two patterns, one forming a passage of $9\frac{13}{16}$ inches in diameter, or 76 square inches in area, designed for walls 1 foot $7\frac{11}{16}$ inches thick; the other having an internal diameter of $8\frac{11}{16}$ inches, or 59 square inches in area, used for walls of 1 foot $3\frac{3}{4}$ inches in thickness. These flues can only secure ventilation in very small rooms, and should not have caps placed on them. Their use is generally limited to rooms warmed by stoves.

VENTILATING FIRE-PLACES.

13. These fire-places, the main idea of which is not new, are, like many other plans proposed by builders, intended to utilize more effectually than the common forms the heat given out by the fuel by introducing a considerable quantity of fresh air, warmed to a moderate degree, to replace that which has passed up the chimney, and also to reduce the amount of cold air entering from the outside through the cracks of the doors and windows. But while the plans at first proposed drew in but a small quantity of fresh air, scarcely equal to one-tenth of that passing out through the chimney, and raised it to temperatures of from 200° to 250° and often more, the forms devised by the ingenious Capt. Douglas Galton for the fire-places of English barracks have furnished a very satisfactory solution of the problem, as has been proved by some experiments made with two fire-places of this kind at the Conservatory of Arts and Trades.*

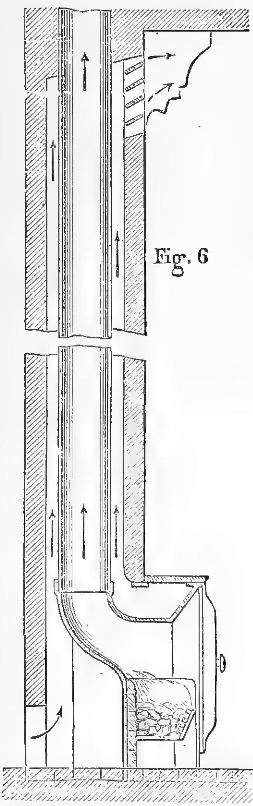


Fig. 6

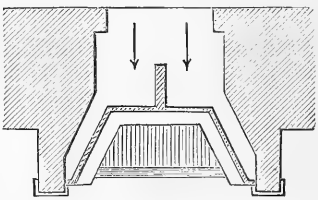


Fig. 7

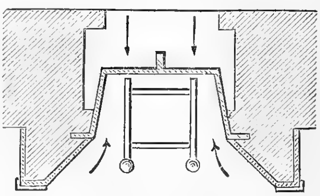


Fig. 8

* Annales du Conservatoire, 6e volume, 1866.

Figs. 6, 7, 8, 9, 10, show that these fire-places consist of an ordinary grate for wood or coal, completely separated from the wall behind. The flue, as far as to the top of the room to be warmed, consists of a cast-iron pipe placed in the center of a shaft extending to the ceiling, and into the latter passes the external air admitted from below, on the side or at the back, according to local conditions.

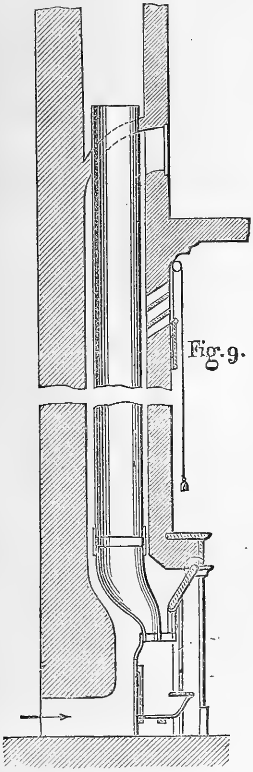
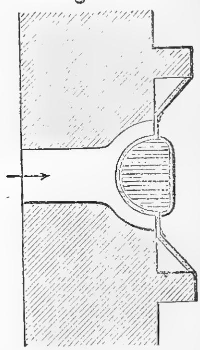


Fig. 9.

Near the ceiling the shaft through which the external air has passed and been warmed contains an opening fitted with inclined slats, which direct the air toward the top of the room. This opening should contain a register, which may be easily opened or closed according as the fire is bright or dull.

Fig. 10.



Observation shows that with the dimensions given below the amount of air thus introduced at 80° differs but little from that passing off up the chimney, so that the admission of cold air through the doors is almost prevented. This introduction of warm air, in addition to the warmth produced by the ordinary radiation from the fire, increases its heating-effect, which becomes as much as 35 per cent. of the heat produced by the fuel, while the common forms of fire-place give but 12 or 14 per cent., and those supplied with Fondet's apparatus but about 20 per cent.

14. In every building where this form of fire-place can be used it is evident that it should be preferred to all others, and in its construction the proportions given below should be followed.

It is well to add that most forms of iron grates suitable for burning coal or coke are easily adapted to this form, provided that it be possible to provide for the admission of the external air.

Size of room to be warmed.	Amount of air to be changed every hour.	Sectional area of smoke-pipe.	Sectional area of shaft.	Sectional area of fresh-air flue.
Cubic feet.	*Cubic feet.*	*Square inches.*	*Square inches.*	*Square inches.*
3, 532	17, 658	78	39	217
4, 238	21, 190	93	47	260
4, 297	26, 487	116	58	326
6, 357	31, 784	140	70	391
7, 770	38, 848	171	85	477
9, 182	45, 911	202	101	564
10, 595	52, 974	233	116	651

Above the room to be warmed, the warm-air shaft is discontinued and the flue carried up in the usual way. If, however, it be desired to use the shaft for warming rooms above, it may be prolonged; a register being fitted to it at each floor to regulate its action.

The hearths of these fire-places should be arranged as in common fire-places. They should be made of cast iron, and the fire-place lined with fire-brick if coal or coke is to be used. A movable blower should be arranged to be used for kindling the fire.

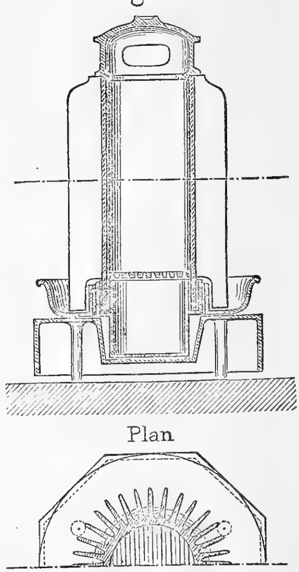
15. *Observation relative to large rooms.*—It is proper to repeat here that the dimensions given for these ventilating fire-places cannot be much increased, even for the largest rooms. But while two fire-places of the usual form, placed in the same room, often interfere with each other, the same difficulty is not experienced with ventilating fire-places, which supply themselves with the air necessary for draught.

Still, in such cases, it is better, in addition to the fire-places, to employ heaters, arranged according to the principles given further on, to be chiefly used in warming vestibules, stairways, corridors, anterooms, &c., only introducing into the living-rooms warm air, which has the moderate temperature of 94° to 100° in the upper portions.

STOVES.

16. *Domestic use.*—Stoves, usually placed within the room, form the most economical method of heating. Those which are made of porcelain, sheet-iron, or cast iron, without hot-air passages, and deriving their supply of air from the rooms in which they are placed, give out into the rooms they warm 85 to 90 per cent. of the heat produced by the fuel. (Fig. 11.)

Fig. 11.



But the amount of air which passes through the stove and escapes up the chimney is only about 80 cubic feet to each pound of wood burned, from 96 to 112 cubic feet to each pound of coal, and from 160 to 192 cubic feet to each pound of coke, even with a brisk fire. Stoves of this kind only produce a very slow change of air, equal, at most, to one-tenth the capacity of the place warmed, the air of which consequently would only be completely changed by them once in ten hours.

Warming by means of stoves is, then, evidently injurious to health. They have, besides, the defect of causing considerable differences between the temperatures which prevail at different heights. These differences may be as much as 18° or 20° in rooms 13 to 16 feet high.

17. *Injurious effects produced by cast-iron stoves.*—Cast-iron stoves are much more injurious than porcelain ones on account of the great and irregular heating of

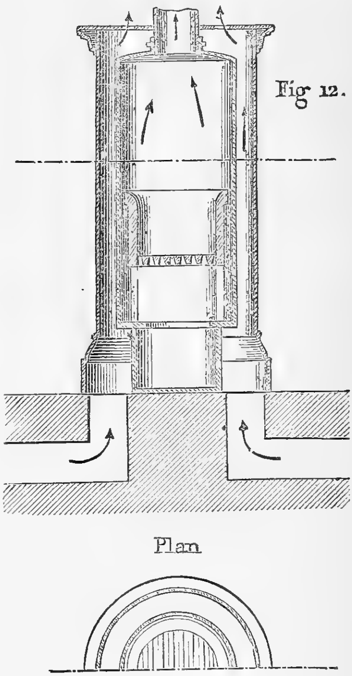
their sides. They are usually so badly made that they should not be used in dwellings. According to some recent direct and careful experiments* made in 1867 by H. Deville and Troost, cast iron, at a red heat, readily allows the passage of gas, especially hydrogen and carbonic acid, which explains the very injurious and even poisonous effects produced by the use of stoves in the rooms of a dwelling. At best, they should only be used for warming passages and such rooms in the house as are frequently opened, or in which the air may be easily changed.

Stoves made of porcelain or sheet-iron are far preferable, and are not subject to the same defects, but they do not secure a more rapid change of air.

It is proper to add, however, that, for some years back, stove-founders have been striving to improve cast-iron stoves, the imperfections of which, though not at first so well known, were still perceived. Stoves are often made at present so that after the fire is started, the opening of movable doors or the removal of blowers converts them into grates detached from the wall, and able, with sufficiently large chimneys, to produce ventilation similar to that of ordinary fire-places. In addition to these plans, many forms of which are made in foundries, if a fire-brick lining, which is easily renewed, be placed in the stoves, the excessive and sudden overheating of the iron and the rapid destruction of the metal will be prevented, and the unpleasant effects resulting from the use of cast-iron stoves much diminished.

Similar arrangements might also be introduced into those little furnaces used at the same time for warming the room and for cooking; as well as in the construction of hot-air furnaces.

Fig 12.



18. *Stoves with circulation of hot air.*—When the air which passes through the pipes and out through the hot-air openings is taken from the room itself, the previously-mentioned unpleasant effects continue, and, besides, since the air from these openings is at a temperature often above 212°, they injuriously affect the people near them, and are unhealthful.

If the hot-air passages and the draught be supplied from the external cold air, a part of the heat given out by the fuel being employed to warm this air, the heating-effect of this apparatus will be slightly increased, because the escaping gases will be less warm; but it will not

* Comptes rendus de l' Académie des sciences, 13 janvier 1868.

be less unhealthful, because the hot air which it furnishes is always at an excessively high temperature.

The removal of the foul air of the room, also, is rather diminished than increased, since the temperature of the escaped gases is less.

19. *Stoves with circulation of air made on the model devised by the late René Duvoir and the General Gas-Light Company.*—These stoves, with which some schools in Paris are provided, and which are recommended to the public by the General Gas-Light Company for coke-burning stoves, utilize 67 per cent. of the heat produced by the fuel.

The escaping products of combustion often have at 13 feet from the fire a temperature of 750° or more. The warm air which passes into the room is as high as 392°, and its volume is only 800 cubic feet for each pound of coal burned, because the passages provided for it are much too small. Those of the usual proportions only produce a change of air of about 2,119 cubic feet an hour, or 352 cubic feet to the pound of coal. They are consequently unhealthful, and do not merit the name of ventilating stoves, which some makers give to them. In order to make them cheap, most stoves of this kind are made with the total heating-surface scarcely equal to twenty times that of the grate, while it should be at least three or four times as much. The surface of the hot-air passages is scarcely equal to that of the grate. This should also be three or four times as much, to increase the amount of air introduced and to reduce the temperature.

The chimney has an area equal to 18 per cent. of that of the stove. It would be well to double it to secure at least a more rapid change of air; but then the heating-effect of the apparatus would be materially reduced.

20. *Portable heaters—Chaussenot's and similar models.*—(Fig. 13.)—This builder has made, for large rooms, hall-ways, &c., stoves with hot-air circulation, which are true heaters, because, before escaping into the air, the products of combustion pass through many pipes, and a considerable amount of warm air may be obtained, drawn, if necessary, from the outside of the building. Their heating effect is as much as 93 per cent. of the heat produced by the fuel. They are capable of introducing into the places to be warmed about 2,551 cubic feet of air for each pound of coal consumed, but the temperature of the air is as high as 266°, or even more, which shows that the passages are not sufficiently large. With their present proportions, they only remove 91 cubic feet of foul air for each pound of coal burned. They are, consequently, unhealthful, and are only suitable for warming passages, such as vestibules, stairways, &c., where the external air enters and mixes freely with the warmed air. In a stove of this kind experimented upon at the conservatory, the total heating-surface is more than one hundred times the grate-surface, which is a good and large ratio. The surface of the air-passages is equal to three times the grate-surface, which is not quite enough.

The chimney has an area equal to 47 per cent. of the grate-surface,

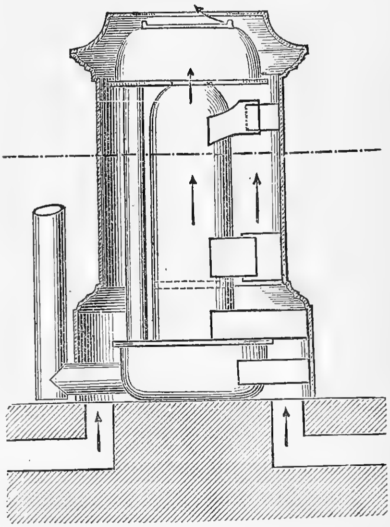
which is enough for draught, but does not secure a sufficiently rapid removal of foul air.

21. *Improvements to be made in the construction of stoves.*—The principal defects of all stoves, without exception, are—

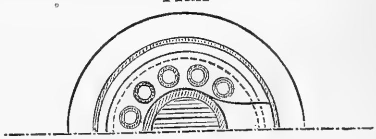
1. Not carrying off foul air as quickly as necessary for health.

2. Giving too high a temperature to the air which passes through them.

Fig. 13.



Plan



The means of lessening these faults are—

1. Making separate ventilating shafts, heated directly by the stove and the chimney.

2. Enlarging also the size of the hot-air passages, and always, when not impossible, taking the air from the outside of the building in order to prevent it from entering through the doors and windows.

3. Furnishing the stoves with doors, which, being opened after the fire is kindled, change them almost into open fire-places, and cause a strong draught in the chimney, the size of which should be enlarged, without fear of increasing too much the expense for fuel.

German stoves and those of some French makers have an arrangement of this kind, though still imperfect.

22. *Fire-places and stoves with reversed draught.*—In some cases the want of a flue above the fire-place renders it necessary to carry the smoke to a horizontal passage below, which conveys it to the bottom of a vertical flue, placed some distance off. To obtain in such a case a draught at the instant of lighting the fire, it is generally necessary to start a small fire in an opening in the horizontal passage at the foot of the vertical flue, which causes a momentary draught; the external supply of air to this fire being stopped as soon as it is kindled, in order that, taking air from the horizontal passage alone, it may produce a current which will extend to the chimney or to the stove. But this arrangement is often insufficient, at least unless the extra fire be kept up, which would be very troublesome.

In houses lighted by gas it is preferable to introduce into the chimney at the occupied story, and not at the level of the lower horizontal passage, gas-jets inclosed in a little metallic chimney $9\frac{13}{16}$ inches to $11\frac{13}{16}$ inches high, with a separate air-supply, in order to prevent it from being extinguished by the smoke. Three or four jets, each consuming

4 cubic feet an hour, are usually enough. The heat given out by the combustion of gas produces in the flue an increase of temperature, which keeps up the draught of the stoves or chimney. After the fire is well started, the gas-jets may be put out. An arrangement of this kind applied at the conservatory to a stove, the draught of which could not be kept up regularly by an extra fire of the usual kind, and which was also in very bad condition, succeeded very well, even during strong winds.

STEAM-HEATING.

24. The rapid circulation of steam even under very slight pressure, and the large amount of heat it gives out in condensing, are the principal advantages of this mode of heating, which only requires, for the passage of the steam, pipes of small dimensions, but it has with the forms of apparatus most in use very grave defects.

Irregularities in the fire affect very sensibly the circulation of steam, and want of attention, especially apt to occur during the night, leads to condensation. When the fire becomes hot again, the steam, which then flows quickly into the pipes, where a partial vacuum has formed, meeting a great deal of condensed water, drives it violently, and the shocks occasionally produce explosions, often cracks and leaks, or at least very frequent disagreeable noises.

These great objections have generally led to the abandonment of warming by direct steam-circulation, except in factories where the escape-steam from the engines is made use of. In that case it flows constantly through large exposed pipes, having a slope sufficient to prevent the accumulation of condensed water. But when it is designed to warm dwellings by carrying the steam through thin floors, the difficulties increase, and all the unpleasant effects become manifest.

Grouvelle, a skillful civil engineer, has designed and constructed for several hospitals an arrangement in which the steam does not directly heat the radiators placed in the rooms, but the steam-pipes heat water placed in those radiators. This system, in consequence of the great density of water and its imperfect conductibility of heat, prevents the too sudden checking of the radiation when the flow of steam is diminished or stopped. These radiators have, on top, a little opening, which prevents the temperature of the water from rising above 212°, and the pipes which furnish a passage for the air coming in from the outside do not allow the temperature of that air to exceed 104° or 113°.

Special arrangements also allow the steam to be carried through the radiators, or through external pipes, so as to moderate the temperature of the room by using only a few of the radiators. But if this plan secures a more regular warmth, it does not prevent trouble from condensation in the pipes passing through the floors, nor from leaks, which are always difficult to discover and to stop. Some accidents which have

happened at Lariboisière Hospital have even shown that this system is not entirely free from sudden ruptures.

The advantages of steam-heating may be retained, without its principal defects, by arranging the circulating-pipes vertically in shafts formed in the thickness of the walls, or specially built for them, as has been done in some wards of the Vincennes Hospital, or as d'Hamelincourt has arranged it for the circulation of water at the company's office at the Northern Railway.

Some of these pipes may be exposed in the form of columns, and be used for warming the hands or the feet, as is done in many establishments in Germany and Switzerland.

These arrangements, which agree very well with the condition that the fresh air should enter near the ceiling, secure the immediate return of the condensed water to the boiler, and, therefore, greatly diminish the effect of leaks, which would be more easily prevented than in the forms usually adopted at present.

Nothing should prevent the adoption, in each ward of a hospital, of an evaporator warmed by steam on Grouvelle's system, in order to promote the comfort of the patients.

It is proper to add that when the radiators and pipes have a heating-surface of 215 to 258 square feet for 35,316 cubic feet capacity of halls, an elevation of temperature of 29° or 32° may be obtained even in the coldest weather. At Lariboisière Hospital the proportion is 280 square feet, and it is evidently greater than necessary. But there remains against steam-heating the charge of being too readily affected by irregularities in the fire, and particularly by want of attention on the part of the firemen, which during the night may be very much prolonged.

HOT-WATER HEATING-APPARATUS.

25. This system of warming, which has been known and in use for a long time with various modifications, is much less apt to cause sudden variations of temperature than the preceding, since hot-water vessels and pipes of equal capacity always contain a much greater number of units of heat than if filled with steam. The great density of water and its steady circulation through the heater long after the fire has become low, maintain a very regular heat in spite of temporary want of attention.

The temperature of the air warmed by this apparatus is always very moderate. It is even difficult to raise it above 100° or 112° with large radiating-surfaces. In this respect this method of heating is very healthful, provided that ample ventilation be maintained in addition.

It is not essential to follow L. Duvoir's plan of placing regulating-receivers in the upper part of the house to which the warm water ascends, in order to secure a sufficiently rapid circulation by the difference in the density of the high ascending and descending columns.

Heating-apparatus of this kind in use at Guy's Hospital, London, at the Sydenham Palace, and all those used in warming green-houses, prove that, provided the pipes be sufficiently large, a small difference in height between the ascending and descending pipes is sufficient to maintain the circulation with even a slight difference of temperature. Another conclusive example is found in the apparatus used in warming some baths.

The hot-water circulating-pipes may be arranged to warm the air either in the lower portions or in vertical shafts built in or against the walls, through which the outside air passes and becomes warmed by contact with the pipes.

The first arrangement, in which the pipes may be in sight throughout their whole length and placed in easily accessible places, renders leaks of little consequence, and allows them to be easily found and stopped.

The second, which is used by d'Hamelincourt, and in which hand-hole plates are placed at the top of each section, gives almost the same facility and allows of the removal of the leakage-water.

Both these plans are more cheaply applied than that which has been adopted by L. Duvoir-Leblanc, who carries the water in the thickness of the floors, and they are free from the somewhat too severe condemnation which has been visited upon the plans of that builder.

In these systems, radiators may be entirely dispensed with or confined to one in each ward for the comfort of the patients.

26. *Proper proportions of heating-surfaces.*—A hot-water heating-apparatus does not give out as much heat as a steam-heating apparatus with the same surface. An examination of the results obtained at Lariboisière Hospital shows that a heating-surface of 291 square feet for rooms with a capacity of 35,316 cubic feet is scarcely sufficient in very cold weather, and we think that it would be better to give to the radiators or receivers placed within the rooms to be warmed at least 323 to 344 square feet of total heating-surface for that capacity of 35,316 cubic feet in places similar to hospitals.

In regard to apparatus placed in cellars and designed to warm air which is carried thence through pipes which may cool it, or into rooms not kept constantly warmed, prudence requires that the heating-surface should be 538 square feet for warming rooms containing 35,316 cubic feet, and it is also necessary that the air should not be carried to a great distance.

In general, this system has a smaller heating-capacity than that in which the water is carried in pipes or through the air-passages.

But when the heater, the pipes, and the radiators are all contained in the room to be warmed, the loss from waste heat is reduced, as in the case of stoves, to that carried off by the chimney. Besides, since the heat requires to be kept moderate, this system unites the advantage of healthfulness to that of economy of fuel, and appears to me as a system of general heating preferable to the other systems employed for the same purpose.

Under these conditions, the total heating-surface might be reduced to 269 square feet for heating rooms of 35,316 cubic feet.

A regular moderate and constant temperature being much better secured by a circulation of water that can be increased, checked, or even stopped, partially or entirely, as well as in the systems making use of steam, we believe that it should generally have the preference, but especially in the case of hospitals.

27. *Heating by the circulation of water of very high temperature.*—In regard to that system of heating by the circulation of water of high temperature known under the name of Perkins's system, where the water often attains a temperature above 572°, it cannot, without danger, be carried through pipes placed in the thickness of the floors or near pieces of wood, which would be slowly affected by so high a temperature and disposed to spontaneous combustion, as more than one fire has shown. Also, at present, in establishments where this system of warming has been adopted, all the pipes are in full view, and hung against the walls or ceilings, which makes a very unpleasant appearance. It is, besides, essential to surround with a grating or case those portions of these pipes which are in contact with the building in order to prevent serious accidents. On all these accounts we do not think it proper in any case to make use of this system of heating.

28. *Combination of hot-water and hot-air heating-apparatus.*—The difficulty of heating by means of a hot-air furnace to a greater distance than 40 or 50 feet horizontally from the heaters may be overcome, as we have said before, by placing in the furnace, either a boiler or tubes, called bottles, leading into the hot-water pipes communicating with the radiators and the return-pipes. In this way a combined system of heating is obtained, one part by warm-air and the other by warm water, the latter being capable of useful effect at a great distance.

29. *Combination of warming and ventilation.*—Apparatus for heating by steam, hot water, and by both air and water may easily be connected with arrangements for direct ventilation; water or steam vessels being placed in the pipes or in the chimney to give it the proper activity.

30. *General conclusions from experiments on heating-apparatus made in 1865–'66.*—Experiments, the results of which I have given in notes appended to the Annals of the Conservatory, together with those which I have already published on fire-places, lead to the following classification of the different forms of heating-apparatus examined, made with reference to their heating-effect; that is, the ratio of the heat which they give out directly or indirectly in the places for which they are intended to that developed by the fuel consumed. The table also shows their advantages and defects as regards ventilation and effect on health:

Classification of heating-apparatus in regard to heating effect.

Forms of apparatus.		Percentage of heating effect.	Remarks.
Ordinary fire-places		10–12	Carry off foul air but do not directly bring in fresh air. Effect of system healthful.
Ventilating fire-places		33–35	Carry off foul air and directly introduce moderately warmed fresh air. Healthful system of heating.
Common stoves, without circulation of air.	Cast iron, burning Coal	90	Produce a very insufficient change of air. Unhealthful system.
	Cast iron, burning Coke	83	
	Porcelain, burning wood, slightly healthful	87	
Metal stoves, with circulation of air taken from the outside or inside.	Model in use in schools in Paris	68	Do not produce sufficient change of air and heat too much the air they introduce. Very injurious system of warming if pipes be of cast iron; slightly healthful if of sheet iron.
	With vertical pipes, Chaussenot's model	93	
Heaters with pipes for circulation of hot air.	Horizontal	63	Cannot directly produce a sufficient removal of foul air and in general supply overheated air, but may easily be modified so as to give out air at 86° or 104°. System injurious when not combined with means of ventilation.
	Vertical	80	
Apparatus for circulation of hot water.	When the pipes and radiators are very numerous with large surface compared with that of the heater	65–75	Easily adapted for the establishment of regular direct ventilation.
	When the boiler, furnace, and all the radiators or pipes are contained in the place to be warmed.	85–90	

VENTILATION.

GENERAL PRINCIPLES.

31. *Properties of air.*—Before giving the rules to be followed and the proportions to be adopted to secure in dwellings a proper change of air, it will be useful to state some general principles of physics relative to the properties of this gas.

Air, composed of 21 per cent. of oxygen and 79 of nitrogen, is a ponderable body. At the temperature of 32°, and under the pressure of 30 inches of mercury, 1,000 cubic feet of air weigh $1\frac{1}{4}$ ounces. It is subject, then, like all other bodies, to the laws of gravity. Its molecules, like those of all gases, are but feebly bound to each other by molecular attractions; the slightest force, the least elevation of temperature, the feeblest reduction of pressure, causing the preponderance of the repulsive forces and separating the elements from each other. On the contrary, the slightest depression of temperature unites more closely the molecules of air, and renders it more dense and heavy.

Air expands under the action of heat and contracts under that of cold, the same as other gases, and its volume varies with the temperature, according to Gay-Lussac's law, expressed by the formula—

$$V=[1+0.002036\,(t-32)]\,V_0=[1+a\,(t-32)]\,V_0$$

in which—

V_0=its volume at 32°, and at the barometric pressure of 30 inches of mercury.

V the volume which it occupies at the temperature t_0; and

a=0.002036=a constant co-efficient obtained by experiment, and which expresses the proportion in which the volume increases for each degree Fahrenheit.

This formula shows that, under the same barometric pressure, a volume of one cubic foot of air at 32° becomes—

$[1+a\ (t-32)]=[1+0.002036\ (t-32)]$ cubic feet in passing to the temperature of t degrees.

If the temperature falls instead of rising, the air contracts, its volume diminishes in cooling, and it follows in this contraction the same law, expressed by the formula—

$$V=[1-.002036\ (t-32)]\ V_0=[1-a\ (t-32)]\ V_0$$

which is the same as the preceding formula if the temperature t is considered plus when above 0 and minus when below.

32. *Variation of density.*—When the temperature of the air rises and its volume increases, its density, or the weight of a cubic foot, diminishes according to a law expressed by the following formula, assuming that the atmospheric pressure remains constantly equal to that of 30 inches of mercury:

$$d=\frac{d_0}{1+a(t-32)}=\frac{0.081}{1+0.002036\ (t-32)}$$

The density or the weight of 1,000 cubic feet of air at different temperatures, calculated by the above formula, is given in the following table:

Temperature by Fahrenheit's thermometer.	Weight of 1,000 cubic feet.	Temperature by Fahrenheit's thermometer.	Weight of 1,000 cubic feet.	Temperature by Fahrenheit's thermometer.	Weight of 1,000 cubic feet.	Temperature by Fahrenheit's thermometer.	Weight of 1,000 cubic feet.
°	*Lbs.*	°	*Lbs.*	°	*Lbs.*	°	*Lbs.*
—4.0	.0875	64.4	.0760	132.8	.0673	201.2	.0603
—0.4	.0868	68.0	.0755	136.4	.0669	204.8	.0600
3.2	.0861	71.6	.0751	140.0	.0665	208.4	.0597
6.8	.0855	75.2	.0748	143.6	.0661	212.0	.0594
10.4	.0849	78.8	.0741	147.2	.0657	215.6	.0591
14.0	.0842	82.4	.0736	150.8	.0653	219.2	.0587
17.6	.0836	86.0	.0731	154.4	.0649	222.8	.0584
21.2	.0829	89.6	.0726	158.0	.0646	226.4	.0581
24.8	.0824	93.2	.0721	161.6	.0642	230.0	.0578
28.4	.0819	96.8	.0716	165.2	.0638	233.6	.0575
32.0	.0811	100.4	.0712	168.8	.0634	237.2	.0572
35.6	.0803	104.0	.0708	172.4	.0631	240.8	.0569
39.2	.0799	107.6	.0703	176.0	.0628	244.4	.0566
42.8	.0794	111.2	.0699	179.6	.0624	248.0	.0563
46.4	.0788	114.8	.0694	183.2	.0620	251.6	.0561
50.0	.0783	118.4	.0690	186.8	.0616	255.2	.0558
53.6	.0777	122.0	.0686	190.4	.0613	258.8	.0555
57.2	.0771	125.6	.0681	194.0	.0610	262.4	.0552
60.8	.0766	129.2	.0677	197.6	.0606	266.0	.0549

33. *Mariotte's law.*—According to this familiar law, the temperature of the air remaining constant, its volume varies inversely as the pressure to which it is exposed, and its density is proportional to those pressures.

34. *General relation between the pressure, volume, temperature, and density of air.*—Calling—

$$\left.\begin{array}{l} d_0,\ V_0,\ P_0, \\ d,\ V,\ P, \\ d',\ V',\ P', \end{array}\right\} \text{The density, the volume, and the pressure corresponding to the temperatures,} \left\{\begin{array}{l} 32 \text{ degrees}, \\ (t'-32) \text{ degrees}, \\ (t-32) \text{ degrees}, \end{array}\right.$$

the following relations result from the combination of Mariotte's and Gay-Lussac's laws:

$$V=V'\frac{[1+0.002036\,(t-32)]\,P'}{[1+0.002036\,(t'-32)]\,P}$$

$$d=d'\frac{[1+0.002036\,(t'-32)]\,P}{[1+0.002036\,(t-32)]\,P'}$$

If we suppose that $t'=0$ and $P=P'=$ one atmosphere, $d'=$ 0.081 pounds, the last formula becomes—

$$d=\frac{0.081}{1+0.002036\,(t-32)}$$

which has been found before.

35. *Principle of Archimedes, its effects.*—Air, like all fluids, follows that elementary principle of physics, according to which a body plunged into a fluid loses a part of its weight equal to that of the displaced fluid.

Thus, at the temperature of 32° and under the pressure of 30 inches, every cubic foot of air in the atmosphere weights 0.000081 pounds; and as it occupies exactly the same space as every other volume of air of the same weight, it remains wherever it is placed, unless disturbed by an external force.

If, on the contrary, the temperature of this cubic foot of air be reduced, for example, in consequence of its contact with some cold body, as a window-pane or a wall, it contracts, its volume is reduced, its density increases, it becomes heavier than the volume of air which it displaces in the mass, which is assumed to remain at about the same temperature. Then the excess of its weight over that of a similar volume tends to make it descend.

Thus, in a place where the general temperature is 68°, if a portion which was at first at that temperature, with a density of 0.0000756 pound to the cubic foot, becomes cooled by contact with a cooler body, such as a window-pane or the walls, at a temperature of 32°, its density will become equal to 0.000081, and each cubic foot will tend to fall with a force equal to the excess of its new weight over that of a cubic foot of the surrounding air, or 0.000081—0.000076=0.000005 pound. This effect is constantly produced in winter, when the surfaces of windows and walls are colder than the air of the warmed apartments.

On the contrary, if the temperature of a part of the air be raised above

the mean temperature of the surrounding air, that air expands, its density diminishes, and each cubic foot, no longer weighing as much as the same volume of the rest of the air, is pressed upward by a force equal to the difference of densities.

Thus, in summer, the air in contact with the window-panes becoming warmed, and, in winter, the same effect being produced by stoves, lights, and even by the people in the room, the air, becoming less dense, rises toward the ceiling.

If, for example, the mean general temperature of any place is 61°, the density of the air is 0.000077 pound, and if owing to the action of the sun the air in contact with the windows becomes raised to 79°, its density becomes 0.000074, and each cubic foot of that air is forced upward by a force equal to 0.000077−0.000074=0.000003 pounds.

36. *Frequency of the preceding effects.*—The effects which we have just mentioned frequently manifest themselves in a very unpleasant way in winter, when a person is seated by a window, in a room where the general temperature is high, and still more sensibly in large halls, lighted by skylights. In the latter case, it is often necessary, to avoid these difficulties, while retaining the lights, to heat the space between the roof and the ceiling to 86° or 104° by means of stoves, examples of which will be given further on.

On the contrary, glazed ceilings, recently introduced into some theaters and palaces to admit the light from a large number of gas jets, also heat the room to a very unpleasant degree.

A similar effect is produced in summer in railroad-stations, courts, workshops, and in large buildings covered with glass roofs in which sufficient ventilation has not been provided. The temperature in such places often rises to 104°, 110°, and more.

37. *Unstable equilibrium of air.*—Cooling and warming effects similar to those just mentioned are constantly taking place in dwellings, the air is never at rest, and the slightest variation in temperature and pressure produces almost endless motion. The air, then, is always in unstable equilibrium.

38. *General principles of ventilation.*—Change of air in occupied places is only rendered necessary by the alteration produced in it by respiration, bodily exhalations, the heat given out by the occupants, by the lights, or by these different causes combined. The many observations which I have made, and a comparison of experiments made by different engineers and by myself, have led me to the following conclusions, which I regard as proper to serve as fundamental principles in the formation of plans for the ventilation of occupied buildings, and especially of hospitals:

1. Ventilation is designed for the removal of foul air and the substitution of fresh air.

2. The principal object of ventilation is the immediate withdrawal of foul air. It should, in general, act as near as possible to the points

where the air is contaminated by injurious exhalations, in order to prevent them from affecting the air of the rooms. Inversely, fresh air should be introduced at points removed from the occupants.

3. The different plans which act by means of a draught, when they are properly proportioned and well made, fulfill better and more surely the foregoing conditions than those which act exclusively by forcing in fresh air. The latter do not, of themselves alone, secure the removal of foul air uniformly and constantly under all circumstances and in all seasons.

4. The introduction of fresh air taken at the desired height and in sufficient quantity may be obtained in most cases by the action of draught alone, and without the help of blowing-apparatus, by making the air-shafts and their openings sufficiently large, and having them properly arranged.

5. The draught may be produced, first, by the fire-places or stoves with their chimneys, which are used for general heating or by similar apparatus; secondly, by the same means, aided, if necessary, by auxiliary fires at the bottom of ventilating-shafts, 50 to 65 feet high in large establishments, when these are needed. The air to be removed should flow toward the base of these shafts; in most cases it should be carried there through one or more channels which branch out and terminate in openings close to the sources of infection.

6. Ventilation, by means of draughts produced by grates and chimneys, is easily adapted in most cases to all the modifications rendered necessary by the size and arrangement of rooms. It approaches, as closely as could be desired, the usual and natural aeration of rooms and apartments; it allows the amount and temperature of the air-currents to be varied as needed. It only requires cheap fire-places and their chimneys and pipes or channels, which, once made, cost little to keep in order. It needs no other attention than the regular supply of fuel to the fires, to which account all the attendance may be charged.

Ventilation by blowing or by mechanical apparatus requires, besides chimneys and ventilating-flues, common to both systems, blowing-engines and steam-engines, with special channels for the introduction of the air-blast. It requires the attention of special laborers, mechanics, and firemen, besides involving expense for repairs.

7. For hospitals or for buildings having several floors, the blowing-system does not give the same guarantees as the other system against carrying foul air from one room to another, nor against the return of foul air through the air-shafts or through cracks in their sides, when an accidental circumstance, as the opening of doors or windows, disturbs the usual pressure and motion of the air in the rooms.

8. Draught maintained by simple fire-places and chimneys, with openings of sufficient size suitably placed for the admission of fresh air, carries off the foul air without the help of any mechanical apparatus, and becomes, except under exceptional circumstances, the readiest

method of securing healthful ventilation as strong as desirable in occupied buildings, and especially in the wards of large hospitals, or in those of small hospitals capable of being warmed by an open grate.

9. As regards those establishments where it would be necessary, under special conditions, to employ mechanical methods of forcing in air, it would always be well to aid their action by a strong draught, particularly affecting those places from which exhalations are supposed to arise.

The latter case seldom occurs in establishments where ventilation must be continually maintained; the amount of air removed and introduced remaining almost always constant. When, on the contrary, this work must be frequently changed from one place to another in the same building, and when the amount of air to be changed differs very greatly from one day or hour to another, as is the case, for example, in Saint George's Hall, Liverpool, where these amounts vary from 1 to 50, it may become necessary, or at least advantageous, to assist the action of the draught produced by heat, by that of a mechanical apparatus to produce a sufficient motion in the air-supply pipes.

These conclusions, based upon the discussion of a large number of experiments made by several observers, have been accepted by the hospital consulting committee of hygiene and medical practice, appointed by the secretary of the interior, under an imperial decree of August 29, 1862. They apply to ventilation of all occupied places, and they serve as foundations for the special rules which we shall present.

39. *Influence of seasons.*—It is important not to forget that, in the winter, ventilation may be secured directly and at the same time as warmth. It is this, in particular, which renders warming by means of fire-places in winter so healthful. But it is proper to repeat that this natural ventilation, due to differences of temperature, which are usually quite small, is essentially inconstant, and, therefore, liable to act alternately in the reverse direction, which would often cause great trouble.

The simple difference of internal and external temperature, and, consequently, of the densities of the external and internal air, are then capable of producing sufficient velocity in the receiving and discharging channels to maintain the renewal of air in a proper manner. Thus is obtained what is called natural ventilation.

40. *Amount of air to be changed every hour to preserve the healthful condition of the room:*

	Cubic feet.
Hospitals:	
For ordinary cases of sickness	2,119–2,472
For surgical and lying-in cases	3,532
During epidemics	3,709
Prisons	1,766
Workshops:	
Ordinary occupations	2,119
Unhealthful occupations	3,532

Barracks:	
During the day	1,059
At night	1,413–1,766
Theaters	1,413–1,766
Assembly-rooms and halls for long receptions	2,119
Halls for brief receptions; lecture-rooms	1,059
Primary schools	42–4,530
Adult schools	883–1,059
Stables	6,357–7,063

These amounts, much larger than those deemed necessary a few years ago, are not at all excessive, and are for the most part based on direct observations.*

In manufactories and other buildings, where the number of persons is not very large, but where other causes may affect the air, the amount to be withdrawn should be determined by the condition that the air in each of these places should be completely changed a certain number of times an hour. Thus, for dwelling-rooms, this change should take place about four or five times an hour.

We will specify further on the proportions to be adopted in some other particular cases.

41. *Proper temperature.*—In well-ventilated places, with a constant change of air, higher temperatures can be easily borne, and even be found pleasant, than those which would be found oppressive where the air is not changed. Nevertheless, the internal temperature should not be kept above the following points:

Nurseries, asylums, and schools	59°
Workshops, barracks, prisons	59°
Hospitals	61°–64°
Theaters, assembly-rooms, lecture-halls	66°–68°

The fresh air introduced should generally have about the temperature it is desired to maintain in the room as soon as this is sufficiently warmed.

If, however, the room has large glass surfaces which cool the air, if there are not many occupants or lights, the fresh air should be warmer, and its temperature may be as much as 86° or 95°.

If, on the other hand, there are many lights burning and large gatherings, the temperature of the fresh air should be a little less than that of the room itself. Trial will readily determine the proper temperature in each case.

42. *Means of regulating the temperature of the fresh air.*—During the period of artificial heating, it is proper to reserve means of mixing with the warm air supplied by the heating-apparatus cool air, the amount of which may be regulated by convenient registers. For this purpose the warm air supplied by the heating-apparatus should be received in a

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special receiver or mixing-chamber, into which the cold air also enters before passing into the distributing-pipes.

43. *General rules, theoretical and practical.*—Theory and experiment agree in showing that, calling—

A the sectional area of a chimney or air-shaft;
H its height;
T′ the temperature of the external air;
T the mean temperature in the shaft;
V the mean velocity of the air in the shaft;
K a numerical co-efficient, constant for each shaft, and depending upon its size and position; and
Q the volume of air passing through in a second,

we have the equations—

$$V = K\sqrt{(T-T')\,H}$$

and

$$Q = K A \sqrt{(T-T')\,H}$$

44. *Consequences of these formulas.*—It follows from these formulas that the velocity, V, of the air or smoke in a chimney is proportional—

1. To the square root of the excess of the temperature of the gases in the chimney over the temperature of the external air;

2. To the square root of the height of the chimney, and that the volume of air or smoke discharged in a second is proportional to the same quantity and also to the sectional area of the flue.

It follows then—

1. That the velocity, V, and, consequently, the volume, Q, of the gases given off by the chimney are increased, or the draught rendered stronger by increasing the height of the chimney.

2. That the volume of gases or air removed are increased by giving a greater sectional area to the chimney.

3. That having given the height, sectional area, and general arrangement of a chimney, or any shaft whatever for air or gas, the volume of air which it will remove will always be the same if the temperature within the shaft always exceeds that of the external air by the same number of degrees.

The latter consequence, perfectly confirmed by observation, renders it necessary to proportion the heating-apparatus, which produces the current for the case, when the temperature of the external air is greatest, and consequently for the summer-season.

45. *Difference of temperature usually sufficient.*—Observations made in mines where the circulation of air is the most extended and complicated, as well as of ventilating arrangements of the largest hospitals and amphitheaters, show that a difference of 36° to 45° between the temperature in chimneys and that of the external air is usually sufficient to produce, throughout the air-passages, the velocities which will be mentioned further on.

In theaters, in consequence of the great number of passages, the difference should be 65° to 72° to secure the necessary discharge.

46. *Insufficiency of natural ventilation.*—It also follows from what precedes that in proportion as the difference of temperatures becomes less the velocity of the circulation of air diminishes, which explains why, if in winter the natural ventilation produced simply by the excess of the temperature of occupied places—usually kept at about 60°—over the external temperature is sufficient in most cases to secure a proper change of air when well-proportioned ventilating-flues have been put up, it is no longer so in spring and still less in summer. In these seasons, natural ventilation becomes inefficient, and, as besides it is not always possible to keep the windows open, it becomes necessary to have recourse to artificial ventilation whenever it is deemed necessary to obtain a regular change of air.

47. *Accidental reversal of the motion of the air.*—When the shafts are not kept at a sufficiently high temperature, it often happens that the motion of the air becomes reversed, and the flues introduce the external cold air instead of causing the discharge of the foul air. This effect is frequently produced in arrangements where, by the introduction and discharge of air, natural ventilation cannot be counted upon, notwithstanding the difference of height in the entry and discharge shafts. This is frequently observed in reception-halls, where, several rooms being thrown into one, the chimneys of some, being heated more or less, serve as discharge-flues, while others bring in cold air. The same effects are also produced in places which are only ventilated a part of the day, such as lecture-rooms, theaters, &c. It then often happens that the motion of the air is periodically reversed. The cold air enters by the discharge-flue, and the warmer air of the places which have been occupied escapes through the openings for the admission of air. This reversal, which produces a useless cooling effect, may be prevented by placing in the air-pipes and channels doors or registers, which may be shut when the ventilation is to be discontinued.

Finally, it is also necessary to close the communication with the places to be ventilated when starting the fire, mentioned further on, placed at the bottom of the ventilating-shaft for producing draught, so as to avoid a down-draught, as in the preceding case, filling the room with smoke. A special air-supply should be reserved for this fire.

48. *Insufficiency of window-openings.*—It is generally believed that opening the windows of a large room will produce a complete change of air, and many physicians think that in hospitals the opening of a certain numbers of windows placed on opposite sides, will have that effect. This is not as true as supposed; and in summer, when the air is still and there is no wind, it often happens that the complete opening of five or six windows, on opposite sides of a large reception-room, coach-house, railroad-station, or riding-school, produces but a very imperfect change

of air, and does not at all prevent an excessive increase of temperature. Examples of this kind are very numerous.

49. *Position of openings for the admission and discharge of air.*—None of these openings should be placed at the level of the floors as builders usually, but improperly place them, because the sweepings fall in them, and soon choke the corresponding flues.

Openings arranged to admit warm or cold air should be placed near the ceiling, or at such a distance from the occupants of the room that they may not perceive any current of air.

When, on the contrary, the openings are placed near the floor the warm air in winter ascends rapidly to the ceiling, while in summer the fresh air, which is heavier, remains at the lower part. In both these cases it is unpleasant to stay near these openings. In public halls and lecture-rooms especially, the admission of air under the seats and between the feet of the audience is improper. In the Palace of Luxembourg and the Chamber of Deputies this mode of introducing air has had to be given up entirely.

Discharge-openings, on the contrary, should, in general, be arranged near the floor, and also in the vertical walls. Some special cases, in which this latter rule must be violated, will be mentioned further on.

50. *Proper velocities of the air in the discharge openings.*—These velocities should increase from the first openings in the room to the chimney, which it is well to make common to all the ventilating-flues of the same house. They should be governed as far as possible by the following:

First ventilating-openings, velocity in one second	1 ft.	4 in. to	2 ft.	4 in.
First collecting-passages	3	3	3	11
Second collecting-passages	4	3	4	7
General discharge-chimney	5	6	6	6

These velocities are easily obtained in most cases by means of an excess of 36° to 45° in the chimney over that of the external air.

51. *Sectional area to be given to openings and flues.*—The total volume of air to be discharged in a second, being calculated in advance according to the number of occupants and the conditions of change of air, dividing this volume by the proper velocity for each passage will give in square feet the free sectional area. By free sectional area is meant the actual passage-way, the gratings which often obstruct it being deducted.

Example.—Take the case of a hospital-ward of twelve beds, to each of which is allowed 2,825 cubic feet of air an hour, making in all 33,900 cubic feet an hour, or 9.42 cubic feet a second, the mean velocity in the channels being 2.3 feet a second, their total section would be $\frac{9.42}{2.3} = 4.1$ square feet. If it be necessary to have one to each bed, the pipe behind each bed should have a section equal to $\frac{4.1}{12} = 0.34$ square feet, and its dimensions should be 7 by 7 inches. The collecting-pipes, which receive

the foul air from the six beds on each side, should discharge 4.715 cubic feet in a second, at the velocity of $3\frac{1}{4}$ feet a second. Their greatest sectional area should be 1.437 square feet, and their dimensions 1 foot by 1 foot 5 inches; but they should be made smaller at first, and proportioned at every point to the amount of air to be removed. The sizes of the other air-passages should be determined in the same way. If there are three stories to each wing, or thirty-six beds in all, the amount of air to be removed will be 101.710 cubic feet an hour, or 28 feet a second. The velocity in the chimney being given at about 7 feet, the area should be 4.3 square feet, and the dimensions 2 feet 1 inch by 2 feet 1 inch.

52. *Proper velocities for the air in fresh-air openings.*—When the openings are placed in the ceiling of the places ventilated, and when the air descends vertically, the velocity of the fresh air should not exceed $1\frac{5}{8}$ feet a second.

When the air is distributed laterally, and almost parallel with the ceiling, or at 16 to 20 feet above the heads of the occupants, the velocity of the entering air may be $3\frac{1}{4}$ feet without inconvenience. Such entering velocities are usually easily produced by the simple effect of the draught, which causes the removal of the air. Thus, in the large lecture-hall of the Conservatory of Arts and Trades, which often contains 750 auditors, to each of whom is allowed 1,059 cubic feet of air an hour, which requires a change of 794,610 cubic feet an hour, or 227 cubic feet a second, the total free section of fresh-air openings is about 129 square feet, and the admission of this large volume of air is scarcely perceptible.

53. *Proper area of fresh-air openings.*—Although in every case a part of the air carried off will be naturally replaced by that which enters through the joints of the doors and windows, it will be well to calculate the free area of the openings for the admission of fresh air by dividing the total amount to be introduced in one second by the fixed velocity of entrance. Thus, the currents of air from the doors and windows will be diminished.

54. *Means of overcoming the effects of currents of air produced by the draught.*—The system of ventilation by direct draught is rightly charged with producing currents of air, often very unpleasant, when the outside doors are open; but the effect of these currents may be rendered less unpleasant by following the preceding rules, and, besides, they may be rendered almost entirely imperceptible by taking care to warm the entrances to ventilated buildings, such as corridors, vestibules, waiting-rooms, &c., so that the opening of doors will only cause the admission of warm air at a temperature at least equal to that of the places to be ventilated. We will specify in each case the particular arrangements to be adopted for this purpose.

[To be continued in the next volume.]

ADDITIONS TO A MEMOIR ON METHODS OF INTERPOLATION APPLICABLE TO THE GRADUATION OF IRREGULAR SERIES.

By E. L. De Forest, M. A.

The memoir referred to may be found at page 275 of the appendix to the Smithsonian Report of 1871. Its contents need not be repeated here, and the reader will be presumed to have that report before him. The formulas and tables we shall now obtain will be numbered consecutively with the previous ones.

INTERPOLATION BY MEANS OF AN ALGEBRAIC FUNCTION.—FIRST METHOD.

The question was left unsettled whether it is best to assume groups of equal extent, as in the case of formulas A, B, C, &c., (pp. 279 to 285,) or to make them of unequal extent and in accordance with Tchebicheff's system of arrangement, as in formulas (40), (41), and (42). Some further investigation has made it seem probable that the latter system, though not always the best, is the most likely to give uniformly good results. It agrees better with Cauchy's method of interpolation, and compares very favorably with that method, so far as can be judged from a few trials which have been made. Hence it is desirable to extend the series of formulas (40), (41), &c., so as to include the cases of six, seven, eight, and nine assumed groups. This has been done, and the numerical co-efficients involved have been carried out to as many as nine significant figures—a larger number than is required in ordinary practice; but it was thought best to compute them, once for all, with as great accuracy as can ever be needed for any purpose. The labor of computation need never be undertaken again, for their accuracy can be easily tested, as follows. Take, for instance, formula (42), and suppose that the terms of the given series are each equal to unity; then in the equation of this series we ought to have $A=1$, while all the other constants, B, C, &c., should be zero. The sums S_1, S_2, S_3, &c., are equal to n_1, n_2, n_3, &c., respectively, so that we have—

$$A = 3.777709 \times .3090170 + \tfrac{2}{5} \times .0954915 - .4111456 \times \tfrac{1}{2} = 1.0000001$$

This differs from unity by only an unit of the seventh decimal place, which is as close an approach to exactness as can be attained without carrying out the decimals farther than is done in formula (42). So, too, in the cases of the constants C and E, we have—

$$C=\frac{1}{N^2}(55.33375\times\tfrac{1}{2}-71.73251\times.3090170-\frac{288}{5}\times.0954915)=\frac{1}{N^2}(-.0000004)$$

$$E=\frac{256}{N^4}(.3090170+2\times.0954915-\tfrac{1}{2})=0$$

The expressions for the alternate constants B and D cannot be put to the same test, because $(S_4 - S_2)$ and $(S_5 - S_1)$ are necessarily zero; so we will make another supposition, namely, that the given series consists of the natural numbers, the middle term being 0, and the successive terms on the right being 1, 2, 3, &c., while those on the left are -1, -2, -3, &c. Here we ought to have, in the equation of the series, $B = 1$, and all the other constants equal to 0. The sums of the terms in the several groups are—

$$S_3 = 0$$

$$S_4 = -S_2 = n_4 \left(\frac{n_3 + n_4}{2} \right)$$

$$S_5 = -S_1 = n_5 \left(n_4 + \frac{n_3 + n_5}{2} \right)$$

Hence we have—

$$B = \frac{1}{N^2} \left\{ 13.088544\, n_4 (n_3 + n_4) - \frac{48}{5} n_5 (2\, n_4 + n_3 + n_5) \right\}$$

$$D = \frac{1}{N^4} \left\{ \frac{512}{5} n_5 (2\, n_4 + n_3 + n_5) - 63.28668\, n_4 (n_3 + n_4) \right\},$$

and substituting the values of n_3, n_4, and n_5, we find—

$$B = 1.00000007 \qquad D = \frac{1}{N^2} (-.0000003)$$

which are very nearly unity and zero, as they ought to be.

The accuracy of each of the following formulas can be tested in a similar way. The five-group formula (42), when the decimals are carried out a little further, becomes—

Formula (79).

$$n_1 = n_5 = \tfrac{1}{2} N \left(1 - \cos \frac{\pi}{5} \right) = .0954915028\, N$$

$$n_2 = n_4 = \tfrac{1}{2} N \left(\cos \frac{\pi}{5} - \cos \frac{2\pi}{5} \right) = \tfrac{1}{4} N$$

$$n_3 = N \cos \frac{2\pi}{5} = .3090169944\, N$$

$$A = \frac{1}{N} \left\{ 3.777708764\, S_3 + \tfrac{1}{5} (S_1 + S_5) - .411145618\, (S_2 + S_4) \right\}$$

$$B = \frac{1}{N^2} \left\{ 13.08854382\, (S_4 - S_2) - \frac{48}{5} (S_5 - S_1) \right\}$$

$$C = \frac{1}{N^3} \left\{ 55.3337474\, (S_2 + S_4) - 71.7325052\, S_3 - \frac{144}{5} (S_1 + S_5) \right\}$$

$$D = \frac{1}{N^4} \left\{ \frac{512}{5} (S_5 - S_1) - 63.2866805\, (S_4 - S_2) \right\}$$

$$E = \frac{256}{N^5} \left\{ S_3 + (S_1 + S_5) - (S_2 + S_4) \right\}$$

The six-group formula can be expressed without decimals:

Formula (80).

$$n_1 = n_6 = \tfrac{1}{2}\,\mathrm{N}\left(1 - \cos\frac{\pi}{6}\right) = \tfrac{1}{4}\,\mathrm{N}\,(2 - \sqrt{3})$$

$$n_2 = n_5 = \tfrac{1}{2}\,\mathrm{N}\left(\cos\frac{\pi}{6} - \cos\frac{\pi}{3}\right) = \tfrac{1}{4}\,\mathrm{N}\,(\sqrt{3} - 1)$$

$$n_3 = n_4 = \tfrac{1}{2}\,\mathrm{N}\cos\frac{\pi}{3} = \tfrac{1}{4}\,\mathrm{N}$$

$$\mathrm{A} = \frac{1}{3\,\mathrm{N}}\left\{(15 - 4\sqrt{3})(\mathrm{S}_3 + \mathrm{S}_4) + 3(\mathrm{S}_1 + \mathrm{S}_6) - (4\sqrt{3} - 3)(\mathrm{S}_2 + \mathrm{S}_5)\right\}$$

$$\mathrm{B} = \frac{4}{3\,\mathrm{N}^2}\left\{19(\mathrm{S}_4 - \mathrm{S}_3) + 3(\mathrm{S}_6 - \mathrm{S}_1) - 5(\mathrm{S}_5 - \mathrm{S}_2)\right\}$$

$$\mathrm{C} = \frac{16}{\mathrm{N}^3}\left\{(5\sqrt{3} - 4)(\mathrm{S}_2 + \mathrm{S}_5) - 4(\mathrm{S}_1 + \mathrm{S}_6) - (11 - 5\sqrt{3})(\mathrm{S}_3 + \mathrm{S}_4)\right\}$$

$$\mathrm{D} = \frac{256}{3\,\mathrm{N}^4}\left\{3(\mathrm{S}_5 - \mathrm{S}_2) - 4(\mathrm{S}_4 - \mathrm{S}_3) - 2(\mathrm{S}_6 - \mathrm{S}_1)\right\}$$

$$\mathrm{E} = \frac{1280}{3\,\mathrm{N}^5}\left\{(\mathrm{S}_1 + \mathrm{S}_6) + (2 - \sqrt{3})(\mathrm{S}_3 + \mathrm{S}_4) - (\sqrt{3} - 1)(\mathrm{S}_2 + \mathrm{S}_5)\right\}$$

$$\mathrm{F} = \frac{1024}{\mathrm{N}^6}\left\{(\mathrm{S}_4 - \mathrm{S}_3) + (\mathrm{S}_6 - \mathrm{S}_1) - (\mathrm{S}_5 - \mathrm{S}_2)\right\}$$

When seven groups are assumd, we get the following:

Formula (81).

$$n_1 = n_7 = \tfrac{1}{2}\,\mathrm{N}\left(1 - \cos\frac{\pi}{7}\right) = .0495155660\ \mathrm{N}$$

$$n_2 = n_6 = \tfrac{1}{2}\,\mathrm{N}\left(\cos\frac{\pi}{7} - \cos\frac{2\pi}{7}\right) = .1387395330\ \mathrm{N}$$

$$n_3 = n_5 = \tfrac{1}{2}\,\mathrm{N}\left(\cos\frac{2\pi}{7} - \cos\frac{3\pi}{7}\right) = .2004844340\ \mathrm{N}$$

$$n_4 = \mathrm{N}\cos\frac{3\pi}{7} = .2225209340\ \mathrm{N}$$

$$\mathrm{A} = \frac{1}{\mathrm{N}}\left\{5.244333412\,\mathrm{S}_4 + .209118318(\mathrm{S}_2 + \mathrm{S}_6) - .525857833(\mathrm{S}_3 + \mathrm{S}_5)\right.$$
$$\left. - \tfrac{1}{7}(\mathrm{S}_1 + \mathrm{S}_7)\right\}$$

$$\mathrm{B} = \frac{1}{\mathrm{N}^2}\left\{24.6748182(\mathrm{S}_5 - \mathrm{S}_3) + \frac{96}{7}(\mathrm{S}_7 - \mathrm{S}_1) - 16.4349544(\mathrm{S}_6 - \mathrm{S}_2)\right\}$$

$$\mathrm{C} = \frac{1}{\mathrm{N}^3}\left\{138.5583290(\mathrm{S}_3 + \mathrm{S}_5) + \frac{288}{7}(\mathrm{S}_1 + \mathrm{S}_7) - 194.1045503\,\mathrm{S}_4\right.$$
$$\left. - 59.2465387(\mathrm{S}_2 + \mathrm{S}_6)\right\}$$

$$\mathrm{D} = \frac{1}{\mathrm{N}^4}\left\{392.527327(\mathrm{S}_6 - \mathrm{S}_2) - \frac{2560}{7}(\mathrm{S}_7 - \mathrm{S}_1) - 286.517454(\mathrm{S}_5 - \mathrm{S}_3)\right\}$$

$$\mathrm{E} = \frac{1}{\mathrm{N}^5}\left\{1685.91223\,\mathrm{S}_4 + 1189.67603(\mathrm{S}_2 + \mathrm{S}_6) - 1533.08214(\mathrm{S}_3 + \mathrm{S}_5)\right.$$
$$\left. - \frac{6400}{7}(\mathrm{S}_1 + \mathrm{S}_7)\right\}$$

$$F = \frac{1}{N^6}\left\{\frac{12288}{7}(S_7 - S_1) + 781.239210\,(S_5 - S_3) - 1407.744414\,(S_6 - S_2)\right\}$$

$$G = \frac{4096}{N^7}\left\{(S_3 + S_5) + (S_1 + S_7) - S_4 - (S_2 + S_6)\right\}$$

The eight-group formula can be expressed without decimals:

$$n_1 = n_8 = \tfrac{1}{2}N\left(1 - \cos\frac{\pi}{8}\right) = \tfrac{1}{4}N\left(2 - \sqrt{2 + \sqrt{2}}\right)$$

$$n_2 = n_7 = \tfrac{1}{2}N\left(\cos\frac{\pi}{8} - \cos\frac{\pi}{4}\right) = \tfrac{1}{4}N\left(\sqrt{2 + \sqrt{2}} - \sqrt{2}\right)$$

$$n_3 = n_6 = \tfrac{1}{2}N\left(\cos\frac{\pi}{4} - \cos\frac{3\pi}{8}\right) = \tfrac{1}{4}N\left(\sqrt{2} - \sqrt{2 - \sqrt{2}}\right)$$

$$n_4 = n_5 = \tfrac{1}{2}N\cos\frac{3\pi}{8} = \tfrac{1}{4}N\sqrt{2 - \sqrt{2}}$$

$$A = \frac{1}{N}\Big[\{4\sqrt{2+\sqrt{2}} - (1+2\sqrt{2})\}(S_4+S_5) + \{2\sqrt{2(2-\sqrt{2})} - 1\}(S_2+S_7)$$
$$- \{1+2\sqrt{2} - 2\sqrt{2(2-\sqrt{2})}\}(S_3+S_6) - (S_1+S_8)\Big]$$

$$B = \frac{4}{N^2}\left\{11(S_5-S_4) + (7-4\sqrt{2})(S_7-S_2) - (4\sqrt{2}-3)(S_6-S_3) - (S_8-S_1)\right\}$$

$$C = \frac{24}{N^3}\Big[\{5+9\sqrt{2} - \sqrt{2-\sqrt{2}}(4+7\sqrt{2})\}(S_3+S_6) + 5(S_1+S_8)$$
$$- \{\sqrt{2-\sqrt{2}}(4+7\sqrt{2}) - 5\}(S_2+S_7) - \{\sqrt{2+\sqrt{2}}(6+4\sqrt{2})$$
$$-(5+9\sqrt{2})\}(S_4+S_5)\Big]$$

$$D = \frac{64}{N^4}\Big\{3(1+2\sqrt{2})(S_6-S_3) + 5(S_8-S_1) - 17(S_5-S_4)$$
$$-3(5-2\sqrt{2})(S_7-S_2)\Big\}$$

$$E = \frac{320}{N^5}\Big[\{\sqrt{2-\sqrt{2}}(6+7\sqrt{2}) - 6\}(S_2+S_7) + 2\{\sqrt{2+\sqrt{2}}(1+3\sqrt{2})$$
$$-(3+4\sqrt{2})\}(S_4+S_5) - 6(S_1+S_8) - \{2(3+4\sqrt{2})$$
$$- \sqrt{2-\sqrt{2}}(6+7\sqrt{2})\}(S_3+S_6)\Big]$$

$$F = \frac{1536}{N^6}\left\{5(S_5-S_4) + (5-\sqrt{2})(S_7-S_2) - (3+\sqrt{2})(S_6-S_3) - 3(S_8-S_1)\right\}$$

$$G = \frac{7168}{N^7}\Big[(S_1+S_8) + (1+\sqrt{2} - \sqrt{2+\sqrt{2}})(S_3+S_6) - (\sqrt{2+\sqrt{2}} - 1)(S_2+S_7)$$
$$- \{\sqrt{2(2+\sqrt{2})} - (1+\sqrt{2})\}(S_4+S_5)\Big]$$

$$H = \frac{16384}{N^8}\left\{(S_6-S_3) + (S_8-S_1) - (S_5-S_4) - (S_7-S_2)\right\}$$

This is so complicated that, for practical purposes, we will employ decimals, as follows:

Formula (82).

$$n_1 = n_8 = \tfrac{1}{2}\mathrm{N}\left(1 - \cos\frac{\pi}{8}\right) = .0380602337\ \mathrm{N}$$

$$n_2 = n_7 = \tfrac{1}{2}\mathrm{N}\left(\cos\frac{\pi}{8} - \cos\frac{\pi}{4}\right) = .1083863757\ \mathrm{N}$$

$$n_3 = n_6 = \tfrac{1}{2}\mathrm{N}\left(\cos\frac{\pi}{4} - \cos\frac{3\pi}{8}\right) = .1622116744\ \mathrm{N}$$

$$n_4 = n_5 = \tfrac{1}{2}\mathrm{N}\cos\frac{3\pi}{8} = .1913417162\ \mathrm{N}$$

$$\mathrm{A} = \frac{1}{\mathrm{N}}\Big\{3.56260914(\mathrm{S}_4 + \mathrm{S}_5) + 1.16478440(\mathrm{S}_2 + \mathrm{S}_7) - 1.66364272(\mathrm{S}_3 + \mathrm{S}_6) - (\mathrm{S}_1 + \mathrm{S}_8)\Big\}$$

$$\mathrm{B} = \frac{1}{\mathrm{N}^2}\Big\{44(\mathrm{S}_5 - \mathrm{S}_4) + 5.37258300(\mathrm{S}_7 - \mathrm{S}_2) - 10.62741700(\mathrm{S}_6 - \mathrm{S}_3) - 4(\mathrm{S}_8 - \mathrm{S}_1)\Big\}$$

$$\mathrm{C} = \frac{1}{\mathrm{N}^3}\Big\{170.1530208(\mathrm{S}_3 + \mathrm{S}_6) + 120(\mathrm{S}_1 + \mathrm{S}_8) - 135.3171087(\mathrm{S}_2 + \mathrm{S}_7) - 91.4672651(\mathrm{S}_4 + \mathrm{S}_5)\Big\}$$

$$\mathrm{D} = \frac{1}{\mathrm{N}^4}\Big\{735.058008(\mathrm{S}_6 - \mathrm{S}_3) + 320(\mathrm{S}_8 - \mathrm{S}_1) - 1088(\mathrm{S}_5 - \mathrm{S}_4) - 416.941992(\mathrm{S}_7 - \mathrm{S}_2)\Big\}$$

$$\mathrm{E} = \frac{1}{\mathrm{N}^5}\Big\{1974.062909(\mathrm{S}_2 + \mathrm{S}_7) + 659.380867(\mathrm{S}_4 + \mathrm{S}_5) - 1920(\mathrm{S}_1 + \mathrm{S}_8) - 1646.323811(\mathrm{S}_3 + \mathrm{S}_6)\Big\}$$

$$\mathrm{F} = \frac{1}{\mathrm{N}^6}\Big\{7680(\mathrm{S}_5 - \mathrm{S}_4) + 5507.76797(\mathrm{S}_7 - \mathrm{S}_2) - 6780.23203(\mathrm{S}_6 - \mathrm{S}_3) - 4608(\mathrm{S}_8 - \mathrm{S}_1)\Big\}$$

$$\mathrm{G} = \frac{1}{\mathrm{N}^7}\Big\{7168(\mathrm{S}_1 + \mathrm{S}_8) + 4060.34584(\mathrm{S}_3 + \mathrm{S}_6) - 6076.73698(\mathrm{S}_2 + \mathrm{S}_7) - 1425.80385(\mathrm{S}_4 + \mathrm{S}_5)\Big\}$$

$$\mathrm{H} = \frac{16384}{\mathrm{N}^8}\Big\{(\mathrm{S}_6 - \mathrm{S}_3) + (\mathrm{S}_8 - \mathrm{S}_1) - (\mathrm{S}_5 - \mathrm{S}_4) - (\mathrm{S}_7 - \mathrm{S}_2)\Big\}$$

Lastly, the nine-group formula is—

Formula (83).

$$n_1 = n_9 = \tfrac{1}{2}\mathrm{N}\left(1 - \cos\frac{\pi}{9}\right) = .0301536896\ \mathrm{N}$$

$$n_2 = n_8 = \tfrac{1}{2}\mathrm{N}\left(\cos\frac{\pi}{9} - \cos\frac{2\pi}{9}\right) = .0868240888\ \mathrm{N}$$

$$n_3 = n_7 = \tfrac{1}{2}\mathrm{N}\left(\cos\frac{2\pi}{9} - \cos\frac{\pi}{3}\right) = .1330222216\ \mathrm{N}$$

$$n_4 = n_6 = \tfrac{1}{2}\mathrm{N}\left(\cos\frac{\pi}{3} - \cos\frac{4\pi}{9}\right) = .1631759112\ \mathrm{N}$$

$$n_5 = \mathrm{N}\cos\frac{4\pi}{9} = .1736481777\ \mathrm{N}$$

$$\mathrm{A} = \frac{1}{\mathrm{N}}\left\{6.718900297\ \mathrm{S}_5 + .238136413\ (\mathrm{S}_3 + \mathrm{S}_7) + \frac{1}{9}(\mathrm{S}_1 + \mathrm{S}_9) - .650752476\ (\mathrm{S}_4 + \mathrm{S}_6) - .140549851\ (\mathrm{S}_2 + \mathrm{S}_8)\right\}$$

$$\mathrm{B} = \frac{1}{\mathrm{N}^2}\left\{40.1146355\ (\mathrm{S}_6 - \mathrm{S}_4) + 19.9343419\ (\mathrm{S}_8 - \mathrm{S}_2) - 25.6631423\ (\mathrm{S}_7 - \mathrm{S}_3) - \frac{160}{9}(\mathrm{S}_9 - \mathrm{S}_1)\right\}$$

$$\mathrm{C} = \frac{1}{\mathrm{N}^3}\left\{283.1606672\ (\mathrm{S}_4 + \mathrm{S}_6) + 67.0638653\ (\mathrm{S}_2 + \mathrm{S}_8) - 409.8722695\ \mathrm{S}_5 - 111.5059994\ (\mathrm{S}_3 + \mathrm{S}_7) - \frac{160}{3}(\mathrm{S}_1 + \mathrm{S}_9)\right\}$$

$$\mathrm{D} = \frac{1}{\mathrm{N}^4}\left\{1053.695090\ (\mathrm{S}_7 - \mathrm{S}_3) + \frac{2560}{3}(\mathrm{S}_9 - \mathrm{S}_1) - 923.898793\ (\mathrm{S}_8 - \mathrm{S}_2) - 823.638243\ (\mathrm{S}_6 - \mathrm{S}_4)\right\}$$

$$\mathrm{E} = \frac{1}{\mathrm{N}^5}\left\{6330.21204\ \mathrm{S}_5 + 3859.01970\ (\mathrm{S}_3 + \mathrm{S}_7) + \frac{6400}{3}(\mathrm{S}_1 + \mathrm{S}_9) - 5527.64697\ (\mathrm{S}_4 + \mathrm{S}_6) - 2594.89398\ (\mathrm{S}_2 + \mathrm{S}_8)\right\}$$

$$\mathrm{F} = \frac{1}{\mathrm{N}^6}\left\{9605.23187\ (\mathrm{S}_8 - \mathrm{S}_2) + 5158.73566\ (\mathrm{S}_6 - \mathrm{S}_4) - \frac{28672}{3}(\mathrm{S}_9 - \mathrm{S}_1) - 8494.59768\ (\mathrm{S}_7 - \mathrm{S}_3)\right\}$$

$$\mathrm{G} = \frac{1}{\mathrm{N}^7}\left\{33866.1397\ (\mathrm{S}_4 + \mathrm{S}_6) + 25281.7661\ (\mathrm{S}_2 + \mathrm{S}_8) - 35452.4678\ \mathrm{S}_5 - 29849.4159\ (\mathrm{S}_3 + \mathrm{S}_7) - \frac{200704}{9}(\mathrm{S}_1 + \mathrm{S}_9)\right\}$$

$$\mathrm{H} = \frac{1}{\mathrm{N}^8}\left\{\frac{262144}{9}(\mathrm{S}_9 - \mathrm{S}_1) + 19011.3716\ (\mathrm{S}_7 - \mathrm{S}_3) - 25613.9516\ (\mathrm{S}_8 - \mathrm{S}_2) - 10115.7395\ (\mathrm{S}_6 - \mathrm{S}_4)\right\}$$

$$\mathrm{I} = \frac{65536}{\mathrm{N}^9}\left\{\mathrm{S}_5 + (\mathrm{S}_3 + \mathrm{S}_7) + (\mathrm{S}_1 + \mathrm{S}_9) - (\mathrm{S}_4 + \mathrm{S}_6) - (\mathrm{S}_2 + \mathrm{S}_8)\right\}$$

We have now the means of representing any given series by an equation of a degree not higher than the eighth, assuming groups of either equal or unequal extent. In constructing the graduated series from such an equation, it will be most convenient to proceed as stated on page 329 of the previous memoir. The work of finding the values of $\mathrm{C}'x^2$, $\mathrm{D}'x^3$, &c., will be much facilitated by using the accompanying table, which shows at once the seven-figure logarithms of the powers of all the values of x which can be required in constructing a series of not more than one hundred terms. Increased accuracy, too, will be attained

by using this table, for care has been taken to make the seventh decimal figure always correct to its nearest value. This would not be the case if the logarithm were taken in the usual way from a seven-figure table, and multiplied by the index of the power required, for then the last figure might be in error by an amount not exceeding half the number of units in the index. For instance, an ordinary table gives

$$\log (1.5)^8 = 8 \times .1760913 = 1.4087304$$

whereas the true value is 1.4087301.

Logarithms of powers of integers and half-integers from 0 *to* 50.

x	$\log x^2$	$\log x^3$	$\log x^4$	$\log x^5$	$\log x^6$	$\log x^7$	$\log x^8$
0.5	$\bar{1}$.3979400	$\bar{1}$.0969100	$\bar{2}$.7958800	$\bar{2}$.4948500	$\bar{2}$.1938200	$\bar{3}$.8927900	$\bar{3}$.5917600
1.0	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
1.5	.3521825	.5282738	.7043650	.8804563	1.0565476	1.2326388	1.4087301
2.0	.6020600	.9030900	1.2041200	1.5051500	1.8061800	2.1072100	2.4082400
2.5	.7958800	1.1938200	1.5917600	1.9897000	2.3876401	2.7855801	3.1835201
3.0	.9542425	1.4313638	1.9084850	2.3856063	2.8627275	3.3398488	3.8169700
3.5	1.0881361	1.6322041	2.1762722	2.7203402	3.2644083	3.8084763	4.3525444
4.0	1.2041200	1.8061800	2.4082400	3.0103000	3.6123599	4.2144199	4.8164799
4.5	1.3064250	1.9596375	2.6128501	3.2660626	3.9192751	4.5724876	5.2257001
5.0	1.3979400	2.0969100	2.7958800	3.4948500	4.1938200	4.8927900	5.5917600
5.5	1.4807254	2.2210881	2.9614508	3.7018134	4.4421761	5.1825388	5.9229015
6.0	1.5563025	2.3344538	3.1126050	3.8907563	4.6689075	5.4470588	6.2252100
6.5	1.6258267	2.4387401	3.2516534	4.0645668	4.8774801	5.6903935	6.5033069
7.0	1.6901961	2.5352941	3.3803922	4.2254902	5.0705882	5.9156863	6.7607843
7.5	1.7501225	2.6251838	3.5002451	4.3753063	5.2503676	6.1254288	7.0004901
8.0	1.8061800	2.7092700	3.6123599	4.5154499	5.4185399	6.3216299	7.2247199
8.5	1.8588379	2.7882568	3.7176757	4.6470946	5.5765136	6.5059325	7.4353514
9.0	1.9084850	2.8627275	3.8169700	4.7712125	5.7254551	6.6796976	7.6339401
9.5	1.9554472	2.9331708	3.9108944	4.8886180	5.8663416	6.8440652	7.8217888
10.0	2.0000000	3.0000000	4.0000000	5.0000000	6.0000000	7.0000000	8.0000000
10.5	2.0423786	3.0635679	4.0847572	5.1059465	6.1271358	7.1483251	8.1695144
11.0	2.0827854	3.1241781	4.1655707	5.2069634	6.2483561	7.2897488	8.3311415
11.5	2.1213957	3.1820935	4.2427914	5.3034892	6.3641870	7.4248849	8.4855827
12.0	2.1583625	3.2375437	4.3167250	5.3959062	6.4750875	7.5542687	8.6334500
12.5	2.1938200	3.2907300	4.3876401	5.4845501	6.5814601	7.6783701	8.7752801
13.0	2.2278867	3.3418301	4.4557734	5.5697168	6.6836601	7.7976035	8.9115468
13.5	2.2606675	3.3910013	4.5213351	5.6516688	6.7820026	7.9123364	9.0426701
14.0	2.2922561	3.4383841	4.5845121	5.7306402	6.8767682	8.0228962	9.1690243
14.5	2.3227360	3.4841040	4.6454720	5.8068400	6.9682080	8.1295760	9.2909440
15.0	2.3521825	3.5282738	4.7043650	5.8804563	7.0565476	8.2326388	9.4087301
15.5	2.3806634	3.5709951	4.7613268	5.9516585	7.1419902	8.3323219	9.5226536
16.0	2.4082400	3.6123599	4.8164799	6.0205999	7.2247199	8.4288399	9.6329599
16.5	2.4349679	3.6524518	4.8699358	6.0874197	7.3049037	8.5223876	9.7398716
17.0	2.4608978	3.6913468	4.9217957	6.1522446	7.3826935	8.6131424	9.8435914
17.5	2.4860761	3.7291141	4.9721522	6.2151902	7.4582283	8.7012663	9.9443044
18.0	2.5105450	3.7658175	5.0210900	6.2763625	7.5316350	8.7869075	10.0421800
18.5	2.5343435	3.8015152	5.0686869	6.3358586	7.6030304	8.8702021	10.1373738
19.0	2.5575072	3.8362608	5.1150144	6.3937680	7.6725216	8.9512752	10.2300288
19.5	2.5800692	3.8701038	5.1601384	6.4501731	7.7402077	9.0302423	10.3202769
20.0	2.6020600	3.9030900	5.2041200	6.5051500	7.8061800	9.1072100	10.4082400
20.5	2.6235077	3.9352616	5.2470154	6.5587693	7.8705232	9.1822770	10.4940309
21.0	2.6444386	3.9666579	5.2888772	6.6110965	7.9333158	9.2555351	10.5777544
21.5	2.6648769	3.9973154	5.3297538	6.6621923	7.9946308	9.3270692	10.6595077
22.0	2.6848454	4.0272680	5.3696907	6.7121134	8.0545361	9.3969588	10.7393814
22.5	2.7043650	4.0565476	5.4087301	6.7609126	8.1130951	9.4652776	10.8174601
23.0	2.7234557	4.0851835	5.4469113	6.8086392	8.1703670	9.5320949	10.8938227
23.5	2.7421357	4.1132036	5.4842714	6.8553393	8.2264072	9.5974750	10.9685429
24.0	2.7604225	4.1406337	5.5208450	6.9010562	8.2812675	9.6614787	11.0416899
24.5	2.7783322	4.1674983	5.5566643	6.9458304	8.3349965	9.7241626	11.1133287
25.0	2.7958800	4.1938200	5.5917600	6.9897000	8.3876401	9.7855801	11.1835201
25.5	2.8130804	4.2196205	5.6261607	7.0327009	8.4392411	9.8457813	11.2523214
26.0	2.8299467	4.2449200	5.6598934	7.0748667	8.4898401	9.9048134	11.3197868
26.5	2.8464917	4.2697376	5.6929835	7.1162294	8.5394752	9.9627211	11.3859670
27.0	2.8627275	4.2940913	5.7254551	7.1568188	8.5881826	10.0195463	11.4509101
27.5	2.8786654	4.3179981	5.7573308	7.1966635	8.6359962	10.0753289	11.5146616
28.0	2.8943161	4.3414741	5.7886321	7.2357902	8.6829482	10.1301062	11.5772643
28.5	2.9096897	4.3645346	5.8193794	7.2742243	8.7290692	10.1839140	11.6387589
29.0	2.9247960	4.3871940	5.8495920	7.3119900	8.7743880	10.2367860	11.6991840
29.5	2.9396440	4.4094660	5.8792881	7.3491101	8.8189321	10.2887541	11.7585761
30.0	2.9542425	4.4313638	5.9084850	7.3856063	8.8627275	10.3398488	11.8169700
30.5	2.9685997	4.4528995	5.9371994	7.4214992	8.9057990	10.3900989	11.8743987

Logarithms of powers of integers, &c.—Continued.

x	$\log x^2$	$\log x^3$	$\log x^4$	$\log x^5$	$\log x^6$	$\log x^7$	$\log x^8$
31.0	2.9827234	4.4740851	5.9654468	7.4568085	8.9481702	10.4395319	11.9308936
31.5	2.9966211	4.4949317	5.9932422	7.4915528	8.9898633	10.4881739	11.9864844
32.0	3.0103000	4.5154499	6.0205999	7.5257499	9.0308999	10.5360498	12.0411998
32.5	3.0237667	4.5356501	6.0475334	7.5594168	9.0713002	10.5831835	12.0950669
33.0	3.0370279	4.5555418	6.0740558	7.5925697	9.1110836	10.6295976	12.1481115
33.5	3.0500896	4.5751344	6.1001792	7.6252240	9.1502688	10.6753136	12.2003585
34.0	3.0629578	4.5944368	6.1259157	7.6573946	9.1888735	10.7203524	12.2518313
34.5	3.0756382	4.6134573	6.1512764	7.6890955	9.2269146	10.7647337	12.3025528
35.0	3.0881361	4.6322041	6.1762722	7.7203402	9.2644083	10.8084763	12.3525444
35.5	3.1004567	4.6506851	6.2009134	7.7511418	9.3013701	10.8515985	12.4018268
36.0	3.1126050	4.6689075	6.2252100	7.7815125	9.3378150	10.8941175	12.4504200
36.5	3.1245857	4.6868786	6.2491715	7.8114643	9.3737572	10.9360501	12.4983429
37.0	3.1364034	4.7046052	6.2728069	7.8410086	9.4092103	10.9774121	12.5456138
37.5	3.1480625	4.7220938	6.2961251	7.8701563	9.4441876	11.0182189	12.5922501
38.0	3.1595672	4.7393508	6.3191344	7.8989180	9.4787016	11.0584852	12.6382688
38.5	3.1709215	4.7563822	6.3418429	7.9273036	9.5127644	11.0982251	12.6836858
39.0	3.1821292	4.7731938	6.3642584	7.9553230	9.5463876	11.1374522	12.7285169
39.5	3.1931942	4.7897913	6.3863884	7.9829855	9.5795826	11.1761797	12.7727768
40.0	3.2041200	4.8061800	6.4082400	8.0103000	9.6123599	11.2144199	12.8164799
40.5	3.2149100	4.8223651	6.4298201	8.0372751	9.6447301	11.2521852	12.8596402
41.0	3.2255677	4.8383516	6.4511354	8.0639193	9.6767031	11.2894870	12.9022709
41.5	3.2360962	4.8541443	6.4721924	8.0902405	9.7082886	11.3263367	12.9443848
42.0	3.2464986	4.8697479	6.4929972	8.1162465	9.7394957	11.3627450	12.9859943
42.5	3.2567779	4.8851668	6.5135557	8.1419447	9.7703336	11.3987225	13.0271114
43.0	3.2669369	4.9004054	6.5338738	8.1673423	9.8008107	11.4342792	13.0677476
43.5	3.2769785	4.9154678	6.5539570	8.1924463	9.8309355	11.4694248	13.1079141
44.0	3.2869054	4.9303580	6.5738107	8.2172634	9.8607161	11.5041687	13.1476214
44.5	3.2967200	4.9450800	6.5934400	8.2418001	9.8901601	11.5385201	13.1868801
45.0	3.3064250	4.9596375	6.6128501	8.2660626	9.9192751	11.5724876	13.2257001
45.5	3.3160228	4.9740342	6.6320456	8.2900570	9.9480684	11.6060798	13.2640912
46.0	3.3255157	4.9882735	6.6510313	8.3137892	9.9765470	11.6393048	13.3020627
46.5	3.3349059	5.0023589	6.6698118	8.3372648	10.0047177	11.6721707	13.3396236
47.0	3.3441957	5.0162936	6.6883914	8.3604893	10.0325871	11.7046850	13.3767829
47.5	3.3533872	5.0300808	6.7067744	8.3834680	10.0601617	11.7368553	13.4135489
48.0	3.3624825	5.0437237	6.7249649	8.4062062	10.0874474	11.7686887	13.4499299
48.5	3.3714835	5.0572252	6.7429670	8.4287087	10.1144504	11.8001922	13.4859339
49.0	3.3803922	5.0705882	6.7607843	8.4509804	10.1411765	11.8313726	13.5215686
49.5	3.3892104	5.0838156	6.7784208	8.4730260	10.1676312	11.8622364	13.5568416
50.0	3.3979400	5.0969100	6.7958800	8.4948500	10.1938200	11.8927900	13.5917600

Before leaving the subject of interpolation by the "first method," it may be well to notice that the formulas (A), (B), &c., which require that the assumed groups should be of equal extent, can be used for the purpose of ordinary interpolation from single terms which are equidistant, and thus may take the place of the ordinary formula for interpolation by finite differences. We have only to regard the single terms as being represented by S_1, S_2, &c., respectively, and to take n_1 and n both equal to unity. Suppose, for instance, that from the three equidistant terms—

$$13 \qquad 21 \qquad 35$$

we wish to interpolate the value midway between the two last. The ordinary formula is—

$$u = a + x\Delta_1 + \frac{x(x-1)}{2}\Delta_2$$

and we have—

$$a = 13, \qquad \Delta_1 = 8, \qquad \Delta_2 = 6$$

so that the equation of the series becomes—

$$u = 13 + 8x + 3x(x-1)$$

and for $x = \frac{3}{2}$ we get $u = 27\frac{1}{4}$, the value sought.

Now, to do the same thing by formula (A), we take—

$$S_1 = 13, \qquad S_2 = 21, \qquad S_3 = 35, \qquad n_1 = n = 1, \qquad S = u$$

and so get—

$$u = 21 + 11x + 3x^2$$

which is the same as the other equation, except that x is reckoned from the middle of the series. To obtain the interpolated term sought, we take $x = \frac{1}{2}$, and it gives $u = 27\frac{1}{4}$, as before.

This mode of procedure will sometimes be preferable to the ordinary one, because the equation it gives will be arranged according to the powers of x instead of according to the successive orders of differences of the series.

SECOND METHOD OF INTERPOLATION WITH AN ALGEBRAIC FUNCTION.

This method, which gives an adjusted or mean value for the middle one of a group of any odd number of terms, by assigning certain "local weights" to the several terms of the group, was at first regarded by the writer as chiefly useful in making a rough adjustment of a given series, preparatory to the application of the first or third method. It appears now, however, that very little can be gained by such preparatory adjustment; the errors obviated by it being probably smaller than other errors, which are almost necessarily incurred by employing the first and third methods when the true law of the series is unknown. But the second method, in its improved forms, is quite worthy to hold a place of its own as an independent system of adjustment. In the previous memoir, (pp. 334 and 335,) some doubt was expressed as to which system of local weights is the best one; but it now seems clear, from the following considerations, that the preference should be given to formulas (69), (71), &c., which render the probable value of the fourth differences of the adjusted series a minimum. On the assumption that the adjusted series ought to be continuous, so that any five consecutive terms in it can be regarded as agreeing very nearly with a curve of a degree not higher than the third, it is easily shown that a minimum value of the probable fourth difference implies a minimum of probable error in the corresponding term of the series. Let u_1, u_2, &c., be any consecutive terms in a series of the third or any lower order; then we have—

$$\Delta_4 = 6u_3 - 4(u_2 + u_4) + (u_1 + u_5) = 0$$

But if each term is subject to a small error of accidental nature, whose probable value is ε, then the probable value of Δ_4, taken without regard to sign, becomes—

$$(\Delta_4) = \varepsilon\sqrt{6^2 + 2(4^2 + 1)} = \varepsilon\sqrt{70} = 8.3666\ \varepsilon$$

and consequently—

$$\varepsilon = .11952\ (\Delta_4)\ . \tag{84}$$

We thus see that the probable error of a term bears a fixed ratio to the

probable value of the corresponding fourth difference, so that if the latter is a minimum, the former will be a minimum also.

In connection with the least-square formulas, given at top of page 327 of the previous memoir, it was stated that those formulas render the probable error of the adjusted term a minimum, and this property was also claimed for them by Schiaparelli, who had obtained them earlier, in a different way, as mentioned on page 335. But these conclusions were reached by estimating the probable error ε_0 of the adjusted series in a manner which was really defective, since it did not take any account of the condition of continuity which that series ought to fulfill. We shall see hereafter how the probable error may be estimated on the other, and, as it seems, the more correct principle.

The formulas (69), (71), &c., being definitely fixed upon as the best, it became desirable to extend them so as to include as many terms as possible, and they have been computed accordingly, for 17, 19, and 21 terms, as follows:

$$u_9 = \frac{1}{1671525}\left\{\begin{array}{l} 334323\,u_9 + 308308\,(u_8+u_{10}) + 238238\,(u_7+u_{11}) \\ +145236\,(u_6+u_{12}) + 56056\,(u_5+u_{13}) - 6664\,(u_4+u_{14}) \\ -32844\,(u_3+u_{15}) - 28424\,(u_2+u_{16}) - 11305\,(u_1+u_{17}) \end{array}\right\} \tag{85}$$

$$u_{10} = \frac{1}{42010995}\left\{\begin{array}{l} 7627477\,u_{10} + 7135128\,(u_9+u_{11}) + 5783778\,(u_8+u_{12}) \\ +3913728\,(u_7+u_{13}) + 1979208\,(u_6+u_{14}) + 411264\,(u_5+u_{15}) \\ -515508\,(u_4+u_{16}) - 767448\,(u_3+u_{17}) - 549423\,(u_2+u_{18}) \\ -198968\,(u_1+u_{19}) \end{array}\right\} \tag{86}$$

$$u_{11} = \frac{1}{76608285}\left\{\begin{array}{l} 12739727\,u_{11} + 12046320\,(u_{10}+u_{12}) + 10115820\,(u_9+u_{13}) \\ +7360320\,(u_8+u_{14}) + 4351320\,(u_7+u_{15}) + 1674432\,(u_6+u_{16}) \\ -222870\,(u_5+u_{17}) - 1149120\,(u_4+u_{18}) - 1213245\,(u_3+u_{19}) \\ -769120\,(u_2+u_{20}) - 259578\,(u_1+u_{21}) \end{array}\right\} \tag{87}$$

The work of computation need never be repeated, for the accuracy of the formulas can be readily tested by the condition that the weights of any one of them, taken together with the eight nearest zero weights, constitute a series of the tenth order. For practical use, it will be most convenient to put the weights in decimal form, and to retain only three places of decimals. These are given, for the whole series of formulas, in Table III.

TABLE III.*

Local weights of adjustment-formulas.

	5	7	9	11	13	15	17	19	21
l_0	.570	.424	.344	.290	.252	.222	.200	.182	.166
l_1	.287	.293	.270	.245	.222	.202	.184	.170	.157
l_2	—.072	.049	.109	.135	.145	.146	.143	.137	.132
l_3		—.054	—.016	.026	.056	.076	.087	.093	.096
l_4			—.035	—.028	—.007	.015	.034	.047	.057
l_5				—.023	—.027	—.018	—.004	.010	.022
l_6					—.015	—.022	—.020	—.012	—.003
l_7						—.010	—.017	—.018	—.015
l_8							—.007	—.013	—.016
l_9								—.005	—.010
l_{10}									—.003
$\frac{\varepsilon'}{\varepsilon}$	.229	.0822	.0366	.0187	.0104	.00642	.00422	.00273	.00185

* For some additions to this table, see Appendix.

The upper line shows the number of terms included by each formula; the weights of the middle terms are found in the second line, those of the terms next to the middle in the third line, and so on. The third decimal figure has in some cases been changed by a single unit, so as to make the algebraic sum of all the weights in each formula exactly unity. (Compare page 324 of the previous memoir.) The lowest line of the table shows the ratio, for each formula, which the probable error ε' of a term in the adjusted series bears to the probable error ε of the corresponding term in the given series. These ratios are obtained in the following manner:

Let any adjustment-formula whatever, comprising $2m+1$ terms, be represented thus:

$$u_0 = l_0 u_0 + l_1 (u_1 + u_{-1}) + l_2 (u_2 + u_{-2}) + \ldots\ldots + l_m (u_m + u_{-m}) \qquad (88)$$

where u_0 is the middle term, u_1, u_2, &c., are the adjacent terms on the right, u_{-1}, u_{-2}, &c., are those on the left, and l_0, l_1, l_2, &c., are the local weights in fractional form. Then, by a process similar to that which was followed in demonstrating formulas (69) and (71), we shall find that the fourth difference of any five consecutive terms in the adjusted series is—

$$\left.\begin{aligned} \Delta'_4 = {} & (6\,l_0 - 8\,l_1 + 2\,l_2)\,u_0 + \{7\,l_1 - 4\,(l_0 + l_2) + l_3\}\,(u_1 + u_{-1}) \\ & + \{6\,l_2 - 4\,(l_1 + l_3) + (l_0 + l_4)\}\,(u_2 + u_{-2}) + \ldots\ldots \\ & \ldots + \{6\,l_{m-2} - 4\,(l_{m-1} + l_{m-3}) + (l_m + l_{m-4})\}\,(u_{m-2} + u_{-(m-2)}) \\ & + \{6\,l_{m-1} - 4\,(l_m + l_{m-2}) + l_{m-3}\}\,(u_{m-1} + u_{-(m-1)}) \\ & + (6\,l_m - 4\,l_{m-1} + l_{m-2})\,(u_m + u_{-m}) + (l_{m-1} - 4\,l_m)(u_{m+1} + u_{-(m+1)}) \\ & + l_m\,(u_{m+2} + u_{-(m+2)}) \end{aligned}\right\} \qquad (89)$$

Now, take the series—

$$l_2,\quad l_1,\quad l_0,\quad l_1,\quad l_2,\quad l_3,\ \ldots\ldots\ldots\ l_m,\quad 0,\quad 0,\quad 0,\quad 0$$

and let its fourth differences be—

$$\Delta_0,\quad \Delta_1,\quad \Delta_2,\ \ldots\ldots\ldots\ \Delta_m,\quad \Delta_{m+1},\quad \Delta_{m+2}$$

then (89) may be written—

$$\left.\begin{array}{l}\Delta'_4 = \Delta_0 u_0 + \Delta_1 (u_1 + u_{-1}) + \Delta_2 (u_2 + u_{-2}) + \dots\dots\dots \\ \qquad \dots\dots\dots + \Delta_{m+2} (u_{m+2} + u_{-(m+2)})\end{array}\right\} \quad (90)$$

If the given series u_0, u_1, u_2, &c., is of an order not higher than the third, and if the adjustment-formula (88) is one which, as we will suppose, expresses the relation between any $2m+1$ terms in a series of the third or any lower order, then the adjusted series will be the same as the original or given one, its fourth differences will be zero, and both members of equation (90) will be equal to zero. But if each term of the given series is liable to deviate from its normal value by an error of accidental nature, whose probable amount is ε, then the probable value of the fourth difference of the adjusted series becomes—

$$(\Delta'_4) = \varepsilon \sqrt{\Delta_0^2 + 2 (\Delta_1^2 + \Delta_2^2 + \Delta_3^2 + \dots\dots\dots + \Delta_{m+2}^2)} \quad (91)$$

If now we denote by ε' the probable error of a single term in the adjusted series, formula (84) gives—

$$\varepsilon' = .11952\ (\Delta'_4)$$

Consequently we shall have—

$$\frac{\varepsilon'}{\varepsilon} = .11952 \sqrt{\Delta_0^2 + 2 (\Delta_1^2 + \Delta_2^2 + \dots\dots\dots + \Delta_{m+2}^2)} \quad (92)$$

This is the desired expression for the ratio which the probable error of a term in the adjusted series bears to that of the corresponding term in the given series. Let us proceed to compute this ratio, when, for example, the eleven-term formula (73) is used, the weights being taken as in Table III. Setting down the series—

.135, .245, .290, .245, .135, .026, —.028, —.023, 0, 0, 0, 0

its fourth differences are found to be—

.050, .041, —.012, —.050, —.045, .000, .064, —.023

and we have—

$$\frac{\varepsilon'}{\varepsilon} = .11952 \sqrt{.050^2 + 2 (.041^2 + .012^2 + .050^2 + .045^2 + .064^2 + .023^2)} = .0187$$

which is the value shown in Table III. To illustrate the fact that this is a minimum value, that is, less than it would be for any other eleven-term formula, we will next take formula (21), in which the weights are in arithmetical progression. Here the series—

23, 34, 45, 34, 23, 12, 1, —10, 0, 0, 0, 0

has for its fourth differences—

44, — 22, 0, 0, 21, — 52, 41, — 10

and, consequently, we have—

$$\frac{\varepsilon'}{\varepsilon} = \frac{.11952}{165} \sqrt{44^2 + 2 (22^2 + 21^2 + 52^2 + 41^2 + 10^2)} = .0818$$

Again, let us try the improved formula (56). Using only three places of decimals, we have the weight-series—

.144, .238, .274, .238 .144, .038, — .029, — .028, 0, 0, 0, 0

whose fourth differences are—

.028, 032, .005, $-$.022, $-$.070, $-$.014, .083, $-$.028

and consequently—

$$\frac{\varepsilon'}{\varepsilon} = .0205$$

Lastly, let us extend the series of least-square formulas at top of page 327 in the previous memoir, so as to include eleven terms; this gives—

$$u_6 = \frac{1}{429}\left\{ 89\, u_6 + 84\,(u_5 + u_7) + 69\,(u_4 + u_8) + 44\,(u_3 + u_9) + 9\,(u_2 + u_{10}) - 36\,(u_1 + u_{11}) \right\}$$

and proceeding as in the case of formula (21), we get—

$$\frac{\varepsilon'}{\varepsilon} = \frac{.11952}{429}\sqrt{2\,(91^2 + 208^2 + 153^2 + 36^2)} = .1088\,.$$

Now, comparing all these four cases, and considering that the accuracy of the adjustments made by any formula is measured by the smallness of the ratio $\frac{\varepsilon'}{\varepsilon}$, we see that formula (73) is the best, (56) nearly as good, (21) considerably inferior, and the least-square formula the poorest of all. It is not to be understood, however, that when the formulas of Table III are used, the probable errors of the adjusted terms will be really as small as indicated by the ratios given in that table. In making use of these or any other adjustment-formulas under the second method, we are obliged to assume, first, that the true law of the given series can be regarded, within the limits of the formula, as being of algebraic form and of an order not higher than the third; secondly, that the probability of error, or of deviation from the true law, is the same for one given term as for another; and, thirdly, that the number of terms included by the adjustment-formula is large enough to make the actual distribution of errors agree with that which is assigned by the theory of probabilities. None of these three assumptions can be regarded as, practically, anything more than a rough approximation to the real state of things in any given case. Hence, we must take the values of $\frac{\varepsilon'}{\varepsilon}$, not as giving absolute measures of the ratio of the probable errors of adjusted and unadjusted terms, but as a means of estimating the relative accuracy attained by the use of different adjustment-formulas. They will also serve to measure the relative smoothness of adjustment, since we have, according to formula (84),

$$\frac{\varepsilon'}{\varepsilon} = \frac{(\varDelta'_4)}{(\varDelta_4)}$$

that is, the probable value of the fourth difference is diminished by adjustment in the same ratio as the probable error.*

The numerical values of the ratio $\frac{\varepsilon'}{\varepsilon}$ given by formula (92) differ greatly

* The actual diminution of the fourth differences, however, is found to be much more rapid than that of the probable errors, and is very nearly that which theory requires.

from the values which would be obtained if we neglected the principle of continuity in the adjusted series. In that case, denoting the probable error of an adjusted term by ε_0, we should have—

$$\frac{\varepsilon_0}{\varepsilon} = \sqrt{l_0^2 + 2\,(l_1^2 + l_2^2 + l_3^2 + \ldots\ldots + l_m^2)}$$

and the system of weights which renders this ratio a minimum is that of the least-square formulas already referred to.

The first two and last two terms of a given series are not reached by any of the formulas of Table III, and it is impossible to adjust them with the same accuracy as other terms. The best we can do, perhaps, is to apply formulas (60) and (61), or sometimes to use only four given terms instead of five, in which case we get by the same method—

$$u_1 = \frac{1}{20}\,(19\,u_1 + 3\,u_2 - 3\,u_3 + u_4) \tag{93}$$

$$u_2 = \frac{1}{20}\,(3\,u_1 + 11\,u_2 + 9\,u_3 - 3\,u_4) \tag{94}$$

When the law of the given series varies so rapidly that any five consecutive terms cannot be regarded as approximating closely to the form of a curve of the third degree, we may have recourse to adjustment-formulas of the nature of (22) and (59), which assume that the series is of an order not higher than the fifth. Then, by processes precisely analogous to those by which formulas (84) and (69) were demonstrated, it can be shown that the probable error of a term bears a fixed ratio to the probable value of the corresponding sixth difference, namely,

$$\varepsilon = .032898\,(\varDelta_6)$$

that the best adjustment-formula is consequently the one which renders the probable sixth difference of the adjusted series a minimum; and that to include only seven terms, this formula is—

$$u_4 = \frac{1}{3059}\left\{ 1959 u_4 + 825\,(u_3 + u_5) - 330\,(u_2 + u_6) + 55\,(u_1 + u_7) \right\} \tag{95}$$

or, to three places of decimals,

$$u_4 = .640\,u_4 + .270\,(u_3 + u_5) - .108\,(u_2 + u_6) + .018\,(u_1 + u_7)$$

The weights of formula (95), taken together with the twelve nearest zero-weights, constitute a series of the sixteenth order. It has been found that the ratio of the probable errors of the adjusted and unadjusted terms is—

$$\frac{\varepsilon'}{\varepsilon} = 0.232$$

In the case of formula (76), for adjusting a double series, the weights of the formula, taken together with the forty nearest zero-weights, constitute a double series or rectangular table of forty-nine terms, whose complete fifth differences $\varDelta_{5+5}$ are equal to zero. The employment of such an adjustment-formula as this involves the assumption that the true law of the given double series is such that any rectangular group of nine terms will satisfy the condition—

$$\varDelta_{2+2} = 4\,u_5 - 2\,(u_2 + u_4 + u_6 + u_8) + (u_1 + u_3 + u_7 + u_9) = 0$$

(See the figure on page 320 of the previous memoir.) By a process strictly analogous to that which we have followed in the case of ordinary series, it can be shown that the probable error of a term in the double series bears a fixed ratio to the probable value of the corresponding complete second difference, namely,

$$\varepsilon = \tfrac{1}{6}\,(\Delta_{2+2})$$

that the formula (76), which renders the probable value of Δ_{2+2} in the adjusted series a minimum, is, therefore, the one which will make the most accurate adjustment; and that the probable errors of the adjusted and unadjusted terms will, in this case, bear to each other the ratio—

$$\frac{\varepsilon'}{\varepsilon} = 0.305$$

If the least-square formula (48) were used, the ratio of error would be increased to—

$$\frac{\varepsilon'}{\varepsilon} = 0.460$$

It was remarked in the previous memoir that formula (48) gives exact results when applied to a double series or table constructed from a complete equation of the third degree. This is also true of (76), and, moreover, such formulas will be found exact in the case of a table constructed from an entire polynomial of any degree whatever in x and y, provided that no term of this polynomial shall contain $x^2\,y^2$ as a factor. This is only a particular case under the general theorem that if we denote by Δ_{m+n} the result of m finite differentiations with respect to x, and n with respect to y, we shall always have—

$$\Delta_{m+n} = 0$$

in a double series constructed from an entire polynomial of any degree whatever in x and y, provided that no term of this polynomial shall contain $x^m\,y^n$ as a factor.

TEST OF A GOOD ADJUSTMENT.

When a table of mortality or other irregular series is to be adjusted, for instance, by one of the formulas of Table III, the question presents itself, Which formula is most suitable for use in the given case? This question cannot be answered definitely in advance, but we can easily see that if only the five-term formula is used, the adjustment may be insufficient; that is, some undulations may be retained which are due to accidental causes, and do not properly belong to the true law of the series. On the other hand, a formula of twenty-one or more terms might smooth out the series too much, so as to obliterate some features of the natural law. The necessary course of procedure will be, to judge as well as we can which formula is most likely to be suitable, and, having adjusted the series by it, to apply some test of its sufficiency. The natural test seems to be this: that on taking the differences between the adjusted and unadjusted terms throughout the series, the system

of residual errors thus obtained should correspond, as nearly as possible, to the theoretical errors of the given series.

To find these theoretical errors, we employ certain known principles of the doctrine of chances. Denoting by p the probability that an event will happen, $(1 - p)$ being the probability that it will fail to happen, we know that if a large number M of trials are made, the most probable result is that the event will happen p M times; that is, the number is more likely to be p M than to be any other particular number assigned. Nevertheless, it will probably be found, on trial, to happen not exactly p M times, but some other number of times which differs from p M by a small quantity or error. If the M trials are repeated a large number of times, the square root of the mean of the squares of the various errors thus obtained is called the "mean error," and its value, according to the theory of probabilities, is—

$$\sqrt{p\,(1 - p)\,\mathrm{M}}$$

Hence, denoting by l the number of persons observed to be living at a given birthday, and by q' the true probability of dying within a year at that age, the number of such persons who actually die within the year will probably be not exactly $q'\,l$, but some other observed number, and the mean error of this observed number will be—

$$\sqrt{q'\,(1 - q')\,l}$$

Dividing this by l, we have for the mean error of the observed probability of dying within a year—

$$\varepsilon_1 = \sqrt{\frac{q'\,(1 - q')}{l}} \qquad (96)$$

A demonstration of the foregoing principles may be found in the Assurance Magazine for October, 1872.

Now, let us consider the table of mortality for insured lives of healthy male persons in England, recently prepared by the Institute of Actuaries, and published by them, in an unadjusted form, in the Mortality Experience of Life Assurance Companies, London, 1869, and in an adjusted form, with commutation-tables, &c., in the Institute of Actuaries' Life-Tables, 1872. From page 273 of the former work we take the observed values of the probability of dying within a year, from age 18 to 91, inclusive, and enter them in column 1 of Table IV, first multiplying them by 100 to save space. This is the same series which we used in Table II of the previous memoir, with only a few small differences, due to the fact that that series was taken from American insurance reports, which gave the data in a somewhat imperfect form. For the ages 10 to 17 and 92 to 99, the defects of the series have been supplied, as in Table II. At some of the other earlier and later ages, some places of decimals have been neglected as having no real value.

TABLE IV.

Age.	(1.) $100q$	(2.) $100\varepsilon_1$	(3.) $100q_{xxi}$	(4.) $100v$	(5.) $\left(\frac{v}{\varepsilon_1}\right)^2$	(6.) Δ_4	(7.) $100\varepsilon_2$
10	.44						
11	.39						
12	.37						
13	.37						
14	.38						
15	.40						
16	.44						
17	.48						
18	.61						
19	.70						
20	.58	.132	.6308	− .051	.15	− .89	.133
21	.70	.123	.6510	.049	.16	.87	.132
22	.62	.098	.6617	− .042	.18	− .89	.106
23	.77	.095	.6661	.104	1.19	.61	.118
24	.686	.079	.6683	.018	.05	.29	.117
25	.514	.061	.6725	− .158	6.71	− 1.01	.114
26	.692	.065	.6818	.010	.02	.98	.108
27	.647	.058	.6969	− .050	.74	− .77	.099
28	.783	.060	.7170	.066	1.21	.68	.093
29	.736	.055	.7393	− .003	.00	− .64	.086
30	.826	.055	.7624	.064	1.35	.68	.077
31	.736	.050	.7857	− .050	1.00	− .65	.071
32	.832	.051	.8091	.023	.20	.42	.071
33	.831	.050	.8331	− .002	.00	− .26	.066
34	.869	.050	.8582	.011	.05	.31	.057
35	.824	.048	.8847	− .061	1.61	− .28	.051
36	.885	.049	.9130	− .028	.32	.09	.048
37	.956	.050	.9418	.014	.08	− .03	.044
38	1.029	.052	.9698	.059	1.28	− .03	.039
39	1.063	.053	.9966	.066	1.56	.32	.038
40	.987	.051	1.0228	− .036	.50	− .42	.039
41	1.047	.052	1.0501	− .003	.00	.17	.041
42	1.071	.053	1.0814	− .010	.04	.17	.039
43	1.059	.054	1.1203	− .061	1.28	− .37	.036
44	1.180	.057	1.1688	.011	.04	.23	.038
45	1.235	.059	1.2267	.008	.02	.16	.039
46	1.251	.061	1.2915	− .040	.44	− .50	.039
47	1.415	.066	1.3607	.054	.67	.61	.043
48	1.409	.067	1.4329	− .024	.13	− .41	.049
49	1.527	.071	1.5083	.019	.07	.08	.052
50	1.650	.075	1.5879	.062	.69	− .06	.052
51	1.741	.079	1.6723	.069	.76	.28	.056
52	1.702	.080	1.7631	− .061	.58	− .08	.070
53	1.719	.083	1.8626	− .144	3.00	− .04	.084
54	1.895	.089	1.9731	− .078	.77	− .68	.084
55	2.296	.101	2.0972	.199	3.88	1.07	.079
56	2.309	.104	2.2366	.072	.48	− .48	.075
57	2.389	.110	2.3935	− .004	.00	− .12	.076
58	2.512	.116	2.5688	− .057	.24	.80	.076
59	2.534	.121	2.7617	− .228	3.53	− 1.66	.078
60	3.114	.139	2.9741	.140	1.02	1.51	.087
61	3.252	.148	3.210	.042	.08	− .52	.092
62	3.461	.159	3.467	− .006	.00	− .06	.117
63	3.737	.172	3.739	− .002	.00	.11	.128
64	4.019	.187	4.020	− .001	.00	− .13	.153
65	4.357	.204	4.304	.053	.07	.02	.228
66	4.67	.222	4.603	.067	.09	.54	.331
67	4.90	.240	4.937	− .037	.02	− .94	.441
68	5.53	.269	5.324	.206	.58	− .55	.520
69	6.10	.300	5.779	.321	1.14	3.20	.569
70	5.60	.307	6.306	− .706	5.29	− 2.18	.604
71	6.22	.343	6.902	− .682	3.96	− 2.99	.608
72	7.97	.409	7.555	.415	1.02	7.59	.636
73	7.87	.438	8.247	− .377	.74	−11.13	.679
74	10.53	.540	8.976	1.554	8.29	12.60	.725
75	9.43	.563	9.750	− .320	.32	− 9.40	.830
76	10.65	.650	10.583	.067	.01	5.51	1.03
77	10.87	.724	11.493	− .623	.74	− 3.47	1.23
78	12.28	.839	12.486	− .206	.06	.55	1.34
79	13.60	.967	13.572	.028	.00	2.95	1.33
80	14.1	1.10	14.770	− .67	.37	− 4.3	1.53
81	16.0	1.31	16.044	− .04	.00	5.1	1.91
82	17.2	1.53	17.311	− .11	.00	−11.5	2.15
83	20.7	1.88	18.513	2.19	1.36	21.0	2.31
84	18.0	2.09	19.607	−1.61	.59	−22.3	2.68
85	21.6	2.58	20.589	1.01	.15	13.3	3.15

TABLE IV—Continued.

Age.	(1.) 100q	(2.) 100ε_1	(3.) 100q_{xxi}	(4.) 100v	(5.) $\left(\frac{v}{\varepsilon_1}\right)^2$	(6.) Δ_4	(7.) 100ε_2
86	21.7	3.04	21.513	.19	.00	2.6	3.70
87	21.8	3.65	22.441	−.64	.03	−27.4	3.88
88	28.	4.7	23.448	4.6	.96	49.	5.67
89	19.	5.2	24.597	−5.6	1.17	−37.	5.55
90	23.						
91	31.						
92	29.						
93	31.						
94	33.						
95	34.						
96	36.						
97	38.						
98	39.						
99	41.						

In order to estimate the mean errors of this series, we turn to page 244 of the Mortality Experience, and there find the data from which it was derived, namely, the number of lives exposed to risk and the number of deaths occurring within a year at each age. For instance, at age 40 the number of lives exposed was 38195, the deaths were 377; and the observed probability of dying within a year is therefore—

$$q = \frac{377}{38195} = .00987$$

To obtain the mean error of this from formula (96), it might seem that we ought to know in advance the true or adjusted value q'; but it has been found by trial that for the purposes of our present investigation it will make no material difference in the final results whether we use any good adjusted value q', or only the observed value q. We have, then, approximately—

$$\varepsilon_1 = \sqrt{\frac{.00987\ (1 - .00987)}{38195}} = .00051$$

and this, multiplied by 100, is entered at age 40 in column (2). Having thus found the mean error of q for all the ages from 20 to 89, we can find the probable error, if desired, by multiplying the mean error by 0.6745.

Now, let us make an adjustment of the given series of values of 100 q by means of one of the formulas of Table III, for instance, the twenty-one-term formula, and denote the results by 100 q_{xxi}. The adjusted series is shown in column (3), for the ages 20 to 89, which are all that can be reached by that formula. To ascertain whether this adjustment is a good and sufficient one, let each of the terms be subtracted from the corresponding term in column (1). The residual errors thus obtained are denoted by 100 v, and are entered in column (4). Assuming that the adjusted values in column (3) are the true ones, each residual in column (4) is the actual error of the corresponding term in column (1), and, theoretically, the sum of the squares of the mean errors in column (2) ought to be equal to the sum of the squares of the actual errors in column (4). But

if we were to add up the squares of the errors in these columns, we should be giving much greater weight to some portions of the series than to others, because the liability to error is much greater in some parts than in others, as is evident from an inspection of column (2), where the mean errors diminish from age 20 to age 35, or thereabouts, and then increase up to the end of the series, being more than ten times larger at age 75 than they are at age 35. We wish to test the applicability of the adjustment-formula used to all parts of the series alike; and to do this we must put the errors on an equality by dividing the terms in column (4) by those in column (2). Each resulting value of $\frac{v}{\varepsilon_1}$ will denote the amount of actual error for every unit of mean error. The squares of these values are entered in column (5). Now, the arithmetical mean of the squares of the units of mean error ought to be equal to the arithmetical mean of the squares of the proportional actual errors. But the former quantity will be unity, therefore the latter ought to be unity also; that is, the arithmetical mean of all the values of $\left(\frac{v}{\varepsilon_1}\right)^2$ ought to be, approximately, unity. This is the proposed test of a good adjustment.

To see how far it is satisfied in the present instance, we compute the arithmetical mean of the seventy terms in column (5), and find that it is only 0.90. But we cannot expect that such a result will be found exactly equal to unity in any given case, for, the number of terms in the series being limited, the actual distribution of errors will vary considerably from that which theory assumes. What we do require is, that the difference from unity should not be greater than the probable error of the arithmetical mean. This probable error can be roughly computed in the usual way. Subtracting the mean value 0.90 from each of the terms in column (5), we find that the sum of the squares of all the remainders is 164.7, and consequently the probable error sought is—

$$0.6745\sqrt{\frac{164.7}{69\times 70}} = 0.12$$

It thus appears that the value 0.90 does not differ from unity by more than its probable error; so that the series (3) satisfies the proposed test, and may be regarded as well adjusted. The mean value of $\left(\frac{v}{\varepsilon_1}\right)^2$ might, however, be brought nearer to unity, if desired, by re-adjusting series (3) with the same formula or some other one from Table III.

And here we may observe that when repeated adjustments are made, the order in which the formulas are used is immaterial. For instance, if a given series is adjusted by the five-term formula of Table III, and that result is adjusted again by the seven-term formula, the series thus obtained is precisely the same as though we had used the seven-term formula first and then the five-term one. And the ratio of the probable error of the final series to that of the original one is, in both cases, theoretically,

$$.229 \times .0822 = .0188$$

Before the adjustment in column (3) was made, several others had been made with different formulas from Table III, the details of which may be omitted here; but the results were that when the five, nine, and fifteen term formulas were used, the arithmetical means of $\left(\frac{v}{\varepsilon_1}\right)^2$ were found to be considerably less than unity, namely,

0.40, 0.58, 0.80

the probable errors being about the same as in the other case; so that none of these adjustments satisfied the test. The mean value of $\left(\frac{v}{\varepsilon_1}\right)^2$ is here seen to increase as the number of terms included by the adjustment-formula is increased.

The test we have proposed may be satisfied by adjusted series obtained in many different ways, the problem of adjustment being really, to some extent, indeterminate, as stated at page 301 of the previous memoir. When the adjusted series (h) in Table II is tried in the same way, within the same limits of age, the arithmetical mean of $\left(\frac{v}{\varepsilon_1}\right)^2$ is found to be 1.05, so that that series also satisfies the test. It is believed, however, that the present adjustment is the better of the two, the arrangement of the weights in the formulas of Table III being such as to make the closest possible approximation to the actual form of a given series. And the writer would here express the opinion that, for the mere purpose of smoothing down irregularities, the second method of adjustment, as perfected in the formulas of Table III, is in most cases preferable to either the first or the third method, both on the ground of simplicity and of accuracy.

So long as the true analytical law of a series remains unknown, it must be considered futile to attempt to fix a precise value for the probable error of an adjusted term. According to the theoretical ratio in Table III, the probable error of a term in series (3) is only .00185 of that of the corresponding term in series (1). But the ratio is really not less than about $\frac{1}{5}$, so far as can be judged from a comparison of several different adjustments which satisfy the test proposed. This discrepancy is owing to the fact already noticed, that the assumptions we are obliged to make regarding the law of the series and the distribution of the errors are only a rough approximation to the real state of things.

MEAN ERRORS ESTIMATED FROM IRREGULARITIES OF SERIES.

When the theoretical mean errors of the terms in a given irregular series cannot be estimated as in column (2) of Table IV, either because the original data are not given, or from other causes, it may still be possible to make a rough approximation to their amount by means of the actual irregularities of the series, provided that it has not been tampered with, but gives the unaltered results of observation. To illustrate, let

us take the fourth differences of the terms in column (1), by means of the formula—

$$\Delta_4 = 6\,u_3 - 4\,(u_2 + u_4) + (u_1 + u_5)$$

The results are entered in column (6). But equation (84) shows that the probable error is approximately equal to the probable fourth difference multiplied by 0.11952. Hence, if we multiply each of the values of Δ_4 by 0.11952, we shall get a system of errors which may be taken to represent the actual errors of the given series (1). But as their sequence will be very irregular, we must take the average, without regard to sign, of a group of adjacent ones numerous enough to get a fair average value, and this will represent the "mean of the errors." We know from theory that the "mean error" is equal to the "mean of the errors" multiplied by 1.2533. Hence, we can get the mean error by taking an average value of Δ_4 without regard to sign, and multiplying it by—

$$0.11952 \times 1.2533 = 0.14979 = 0.15 \text{ nearly.}$$

If the average of fifteen values of Δ_4 is used, the process amounts simply to taking the sum of every fifteen adjacent terms in column (6) without regard to sign, and dividing it by 100. The results are given in column (7), for the ages 27 to 82. For instance, at the age 40 the sum of the nearest fifteen terms in column (6) is 3.95, and dividing by 100 we have 0.39 as entered in column (7). To get the first seven and last seven terms of this series, an average of less than 15 values of Δ_4 was employed.*

The mean errors thus obtained are denoted by ε_2, to distinguish them from the theoretical mean errors ε_1. The differences between the values of ε_1 and ε_2, though considerable, are sometimes in excess and sometimes in defect, and are, perhaps, no greater than we ought to anticipate, from the usual discrepancies between theoretical and actual systems of errors. It is thought that this method of obtaining the mean error may be useful, at least for purposes of rough estimation, in those cases where the more exact method cannot be applied.

To find the probable errors directly from the average values of Δ_4, we should multiply the latter by—

$$0.14979 \times 0.67449 = 0.10103$$

that is, the probable error is about one-tenth of the average fourth difference.

INTRINSIC WEIGHTS OF OBSERVED TERMS.

We have hitherto proceeded on the assumption that the terms included by an adjustment-formula are all equally liable to error, or deviation from the true law of the series. It is possible, however, to assign to each term its own proper liability to error; that is to say, its own

* It would have been better to have obtained all the averages from only nine or eleven values of Δ_4, instead of fifteen. Owing to the general curvature of the series, the average of a group of terms differs a little from the normal average of the middle term, and this error increases nearly as the square of the number of terms in the group.

intrinsic weight. This was attempted in formula (24) of the previous memoir. We should now prefer to use one of the formulas of Table III, rather than (16), and so write—

$$u_3 = \frac{.570\, c_3\, u_3 + .287\, (c_2\, u_2 + c_4\, u_4) - .072\, (c_1\, u_1 + c_5\, u_5)}{.570\, c_3 + .287\, (c_2 + c_4) - .072\, (c_1 + c_5)} \tag{97}$$

The numerator here is formed by taking the series of products $c_1\, u_1$, $c_2\, u_2$, &c., which are obtained by multiplying each given term by its intrinsic weight, and adjusting them by formula (69). The denominator is formed by adjusting the series of intrinsic weights alone with the same formula. The adjusted value of u_3 is consequently exact whenever the series of products and the series of intrinsic weights are both of an order not higher than the third. But the product of two algebraic and entire polynomials is of a degree equal to the sum of the degrees of the two factors. Hence, formula (97) will give exact results whenever the observed terms u_1, u_2, &c., and their intrinsic weights c_1, c_2, &c., form two series of such orders that the sum of their indices does not exceed 3. Such will be the case, for example, when the former series is of the second order, and the latter is of the first order, or an arithmetical progression. Generally speaking, there is no necessity that the intrinsic weights should follow any sequence at all, but in the case of a table of mortality they ordinarily do, the number of lives observed being, in a rough way, a function of the age, as can be seen in the column of numbers "Exposed to risk," at page 244 of the Mortality Experience already referred to, the numbers increasing continuously up to age 40, where they are at a maximum, and then diminishing continuously to the close of life. If it would be too much to assume that any five consecutive numbers in this series are in arithmetical progression, we can more safely say that any seven of them form, approximately, a series of the second or third order. Now, let us employ formula (95), which gives exact results when applied to a series of the fifth or any lower order Taking the intrinsic weights into account, we shall have—

$$u_4 = \frac{.640\, c_4\, u_4 + .270\, (c_3\, u_3 + c_5\, u_5) - .108\, (c_2\, u_2 + c_6\, u_6) + .018\, (c_1\, u_1 + c_7\, u_7)}{.640\, c_4 + .270\, (c_3 + c_5) - .108\, (c_2 + c_6) + .018\, (c_1 + c_7)} \tag{98}$$

and this will be exact whenever the observed terms u_1, u_2, &c., and their intrinsic weights c_1, c_2, &c., form two series the sum of whose indices does not exceed 5. Such will be the case, for instance, when the former series is of an order not higher than the third, and the latter is of an order not higher than the second, or *vice versa*.

In applying this or any similar formula to the adjustment of a series, such as (1) in Table IV, we can employ the known principle that the intrinsic weights are inversely proportional to the squares of the mean errors, and so take

$$c = \left(\frac{1}{100\, \varepsilon_1}\right)^2$$

But there is reason to think that, in most cases, it is not best to take the intrinsic weights into account. If the observed terms u_1, u_2, &c.,

and their weights c_1, c_2, &c., form two series the sum of whose indices does not exceed 3, then the adjusted value which formula (97) gives is not at all different from that which (69) will give when the intrinsic weights are neglected. So, too, when the sum of the indices does not exceed 5, we get the same result by using formula (95) and neglecting the intrinsic weights, as we would get by taking them into account and using formula (98). From this we may infer that when the intrinsic weights form a regular sequence, it will make no great difference whether we take them into account or not. But the more important point to notice is, that the intrinsic weights of different terms do not bear to each other the same relation as the weights of different observations of the same term would do. For instance, in observing the value of u_4 in formula (98), any m observations, each of whose weights is n, are precisely equivalent to any n observations each of whose weights is m; but these m or n observations of u_4 cannot be fully replaced by any number of observations of u_1 or u_7, because those are quantities differing from u_4 in magnitude, and their relation to u_4 is but imperfectly known. This consideration indicates that in making adjustments, the intrinsic weights should be used only to a limited extent, if at all, and that the best we can do is to observe the value of each term as accurately as possible, and then regard all the terms as of equal weight, or nearly so.

The same consideration will prevent our assigning different intrinsic weights to the several terms combined together to form the sums S_1, S_2, &c., in the first method of interpolation.

ADJUSTMENT-FORMULAS OF OTHER WRITERS.

Before quitting the subject of interpolation by the second method, the present writer would observe that the process by which the new Institute of Actuaries' Life-Tables were adjusted, and which was first published in the London Assurance Magazine for July, 1870, is really a special case under this method, and by merely changing its notation, can be reduced to the formula—

$$u_8 = .200\,u_8 + .192\,(u_7 + u_9) + .168\,(u_6 + u_{10}) + .056\,(u_5 + u_{11}) + .024\,(u_4 + u_{12}) + .000\,(u_3 + u_{13}) - .016\,(u_2 + u_{14}) - .024\,(u_1 + u_{15})$$

Its publication was of later date than my first proposal of formulas of this character for adjusting mortality-tables. The earlier portions of my memoir, which contained formulas (13), (14), (15), and one or two others of similar character, were presented to the Smithsonian Institution, and were sent by it to England for examination, in the summer of 1868. The formulas (17), (19), (20), &c., in which the weights form arithmetical progressions, were presented later in the same year. When these are extended so as to include fifteen terms, we get—

$$u_8 = \frac{1}{140}\Big\{ 28\,u_8 + 23\,(u_7 + u_9) + 18\,(u_6 + u_{10}) + 13\,(u_5 + u_{11}) + 8\,(u_4 + u_{12}) + 3\,(u_3 + u_{13}) - 2\,(u_2 + u_{14}) - 7\,(u_1 + u_{15}) \Big\}$$

and this is a better formula than the English one, as can be readily

shown by comparing the respective ratios of the probable errors of the adjusted and unadjusted terms, computed according to formula (92).

The adjusted series of probabilities of dying within a year at each age, given at page XCIV of the Institute of Actuaries' Life-Tables, was not obtained directly from the corresponding observed series; but the sufficiency of its adjustment can be tested all the same; and on comparing it with the observed series, we find that the arithmetical mean of $\left(\frac{v}{\varepsilon_1}\right)^2$ between the ages 20 and 89, inclusive, is only 0.82. This value falls short of unity by more than its probable error, and indicates that the series in question has not been smoothed out quite enough to give it the greatest accuracy attainable.

The earliest publication of adjustment-formulas of the kind we have been considering, so far as I am aware, is that of Schiaparelli, already referred to, (Smithsonian Report of 1871, page 335.) As his work may not be generally accessible, it is perhaps well to state what that general relation is, which he discovered to exist between the numerical co-efficients which we have called *local weights*. The notation of formula (88) being used, it amounts to this: that if the formula is such as to give exact results when applied to a series of the third or any lower order, we shall have the two conditions—

$$l_0 + 2(l_1 + l_2 + l_3 + \dots\dots + l_m) = 1$$
$$1^2 l_1 + 2^2 l_2 + 3^2 l_3 + \dots\dots + m^2 l_m = 0$$

But if the formula is exact in the case of a series of the fifth or any lower order, like our formulas (22) and (59), then to the above conditions this third one is added—

$$1^4 l_1 + 2^4 l_2 + 3^4 l_3 + \dots\dots + m^4 l_m = 0$$

If the formula holds good for a series of the seventh or any lower order, as in the case of (23), we have a fourth condition—

$$1^6 l_1 + 2^6 l_2 + 3^6 l_3 + \dots\dots + m^6 l_m = 0$$

and so on for formulas of higher orders.

INTENSITY OF MORTALITY.

Writers on the law of mortality have often made use of what is called the intensity or force of mortality, meaning thereby the ratio of deaths to population at any given instant of age. If we consider a stationary population, and denote by y the number of persons who annually attain a given year of age or birthday, and denote by x the age in years, then $y\,dx$ will represent the number living at the exact age x, and $-dy$ will represent the number dying at that exact age. The intensity of mortality then is—

$$\mu = -\frac{dy}{y\,dx}$$

If it were possible to discover the true analytical form of the function which expresses the relation between mortality and age, this quantity μ would naturally be the essential element in it. But if the hope of dis-

covering the true law is chimerical, as there seems much reason to think, it may be doubted whether the quantity μ can have much practical importance. We will proceed, however, to obtain some formulas for finding the intensity, which cannot be directly observed, from the observed quantities; and, conversely, for finding the latter from given values of the intensity.

Let us consider any five consecutive birthdays, and let the numbers of persons annually reaching them be—

$$y_1, \qquad y_2, \qquad y_3, \qquad y_4, \qquad y_5$$

We will assume that the relation of these numbers to the ages may be regarded, within the limits of these five years, as being of algebraic form and of a degree not higher than the third, so that we have—

$$y = \text{A} + \text{B}\,x + \text{C}\,x^2 + \text{D}\,x^3$$

We will also suppose, for simplicity, that the age x is reckoned from the middle birthday, taken as an origin of co-ordinates. Then assigning to x in succession the values -2, -1, 0, $+1$, and $+2$, we have—

$$\begin{aligned} y_1 &= \text{A} - 2\,\text{B} + 4\,\text{C} - 8\,\text{D} \\ y_2 &= \text{A} - \text{B} + \text{C} - \text{D} \\ y_3 &= \text{A} \\ y_4 &= \text{A} + \text{B} + \text{C} + \text{D} \\ y_5 &= \text{A} + 2\,\text{B} + 4\,\text{C} + 8\,\text{D} \end{aligned}$$

and these equations determine the values of the constants. We find—

$$\text{A} = y_3, \qquad \text{B} = \tfrac{1}{12}\{\,8\,(y_4 - y_2) - (y_5 - y_1)\,\}$$

But when $x = 0$, we have $y = \text{A}$ and $\dfrac{dy}{dx} = \text{B}$, so that the intensity of mortality at the middle birthday is—

$$\mu_3 = -\frac{dy}{y\,dx} = -\frac{\text{B}}{\text{A}}$$

and consequently—

$$\mu_3 = \frac{8\,(y_2 - y_4) - (y_1 - y_5)}{12\,y_3} \tag{99}$$

which is the formula sought. Thus, if we have found by observation the numbers of persons annually attaining any five consecutive birthdays, or, what amounts to the same thing, the "numbers living" at those five ages out of a given number of persons born, the above formula will give the intensity of mortality at the middle birthday. It is a little more accurate than the usual formula,

$$\mu_2 = \frac{y_1 - y_3}{2\,y_2}$$

The numerical value of μ does not differ very greatly from that of the probability of dying within a year.

We turn now to the converse problem, that of finding the probability of living one year, or of dying within a year, from certain given values of the intensity of mortality. Let μ_1, μ_2, μ_3, μ_4, be the intensities at any

four consecutive birthdays, and let us assume that they are connected with the age by the law—

$$\mu = -\frac{dy}{y dx} = \text{A} + \text{B}\,x + \text{C}\,x^2 + \text{D}\,x^3$$

Placing the origin of co-ordinates at the middle, and assigning to x in succession the values $-\frac{3}{2}$, $-\frac{1}{2}$, $+\frac{1}{2}$, and $+\frac{3}{2}$, we have—

$$\begin{aligned} \mu_1 &= \text{A} - \tfrac{3}{2}\,\text{B} + \tfrac{9}{4}\,\text{C} - \tfrac{27}{8}\,\text{D} \\ \mu_2 &= \text{A} - \tfrac{1}{2}\,\text{B} + \tfrac{1}{4}\,\text{C} - \tfrac{1}{8}\,\text{D} \\ \mu_3 &= \text{A} + \tfrac{1}{2}\,\text{B} + \tfrac{1}{4}\,\text{C} + \tfrac{1}{8}\,\text{D} \\ \mu_4 &= \text{A} + \tfrac{3}{2}\,\text{B} + \tfrac{9}{4}\,\text{C} + \tfrac{27}{8}\,\text{D} \end{aligned}$$

from which the four constants can be found, and we have—

$$\begin{aligned} \text{A} &= \tfrac{1}{16}\,\{9\,(\mu_2 + \mu_3) - (\mu_1 + \mu_4)\} \\ \text{C} &= \tfrac{1}{4}\,\{(\mu_1 + \mu_4) - (\mu_2 + \mu_3)\} \end{aligned}$$

But integration gives us—

$$-\log' y = \text{A}\,x + \tfrac{1}{2}\,\text{B}\,x^2 + \tfrac{1}{3}\,\text{C}\,x^3 + \tfrac{1}{4}\,\text{D}\,x^4 + \text{constant.}$$

At the second birthday, taking $x = -\frac{1}{2}$ and $y = y_2$, we have—

$$-\log' y_2 = -\tfrac{1}{2}\,\text{A} + \tfrac{1}{8}\,\text{B} - \tfrac{1}{24}\,\text{C} + \tfrac{1}{64}\,\text{D} + \text{constant;}$$

and at the third birthday, with $x = \frac{1}{2}$ and $y = y_3$, we have—

$$-\log' y_3 = \tfrac{1}{2}\,\text{A} + \tfrac{1}{8}\,\text{B} + \tfrac{1}{24}\,\text{C} + \tfrac{1}{64}\,\text{D} + \text{constant.}$$

Subtraction of the first of these two equations from the second gives—

$$-\log'\left(\frac{y_3}{y_2}\right) = \text{A} + \tfrac{1}{12}\,\text{C}$$

But $\dfrac{y_3}{y_2}$ is the probability p_2 of living one year from the second birthday; so that, substituting the values of A and C, we have—

$$-\log' p_2 = \tfrac{1}{24}\,\{13\,(\mu_2 + \mu_3) - (\mu_1 + \mu_4)\} \qquad (100)$$

and this is the formula sought. If, for example, μ_1, μ_2, &c., denote the intensities at the ages 39, 40, 41, and 42, then $\log' p_2$ will be the Napierian logarithm of the probability that a person aged 40 will live at least one year, and $1 - p_2$ is the probability of dying within the year.

INTERPOLATION BY MEANS OF A CIRCULAR FUNCTION.

We have already noticed that the algebraic formulas (A), (B), (C), &c. of the previous memoir can be employed in place of the usual formula of finite differences, for making ordinary interpolations from single terms taken as data. In a similar way, the circular formulas (*a*), (*b*), (*c*), &c., given at page 336 of the memoir, are capable of being used for the purpose of ordinary interpolation, and may thus take the place of such formulas as are found in the appendix to vol. II of Dove's Repertorium, page 275. The given single terms are supposed to be either three, four, six, eight, or twelve in number, and to be situated at equal intervals throughout the whole circular period. We have only to regard them as consecutive areas represented by S_1, S_2, &c., respectively, and take n equal to unity. For example, let there be four of these given terms or equidistant values of the function, namely,

7, 12, 5, 9

then the four-term formula (*b*) gives—

$$A = 8\tfrac{1}{4}, \qquad B_1 = -2\tfrac{1}{2}, \qquad C_1 = \tfrac{1}{2}, \qquad B_2 = -2\tfrac{1}{4}$$

and substituting these values in formula (78), and taking—

$$\theta = \frac{2\pi}{N} = \frac{2\pi}{4} = 90^\circ, \qquad n = 1, \qquad S = u$$

we get the equation—

$$u = 8.25 + \tfrac{1}{2} \sin 45^\circ \{-5 \sin (x\theta) + \cos (x\theta)\} - 2.25 \sin 2\,(x\theta)$$

which is transformable into—

$$u = 8.25 + 1.803 \sin (x\theta + 168^\circ\, 41') - 2.25 \sin 2\,(x\theta)$$

When the values $-\frac{3}{2}$, $-\frac{1}{2}$, $+\frac{1}{2}$, $+\frac{3}{2}$, &c., are successively assigned to x in this equation, the resulting values of u will be the four given terms or data, and for any assumed intermediate values of x intermediate values of the function can be interpolated.

One of the formulas of the Repertorium above mentioned, the one which includes twelve given terms, is the same as the formula subsequently demonstrated and used by Everett, with a different notation, in his articles on "Reducing observations of temperature," in the American Journal of Science and Arts for January and September, 1863. In connection with the remarks made at page 314 of my previous memoir, respecting Everett's method of correcting annual equations of temperature, it ought perhaps to be said that I have not had access to the Edinburgh New Philosophical Journal for July, 1861, in which his work was first published; but the method is presumed to have been essentially reproduced by him in the American Journal for January, 1863. (See foot-note on page 27 of the latter.)

INTERPOLATION BY MEANS OF AN EXPONENTIAL FUNCTION.

In the discussion of this subject at page 329 of the previous memoir, all the roots of the equation of relation were supposed to be real and positive. We shall now consider the general case in which the roots may be either real or imaginary, and shall proceed as before, after the analogy of Prony's treatment of the subject of ordinary interpolation from single terms or ordinates. Instead of placing the origin of co-ordinates at the middle of the left-hand group as before, we shall now place it at the middle of the series. This is equally convenient, and more symmetrical and accordant with the system we have followed in the cases of algebraic and circular functions.

The appearance of imaginary roots in the equation of relation implies a change in the form of the function whose equidistant values constitute the recurring series. Just as each real and positive root corresponds to a term of the form $b\,\beta^x$ in the function, so each pair of imaginary roots corresponds to a term of the form—

$$\{c \sin (x\theta) + d \cos (x\theta)\}\, \gamma^x$$

where c, d, and γ are constant numbers, and θ is a constant arc. Now, let us write the equation of the curve as follows:

$$\left.\begin{aligned} y = {} & A + B(\log'\beta)\beta^x + B_1(\log'\beta_1)\beta_1^x + B_2(\log'\beta_2)\beta_2^x + \&c. \\ & + \{(C\log'\gamma - D\theta)\sin(x\theta) + (D\log'\gamma + C\theta)\cos(x\theta)\}\gamma^x \\ & + \{(C_1\log'\gamma_1 - D_1\theta_1)\sin(x\theta_1) + (D_1\log'\gamma_1 + C_1\theta_1)\cos(x\theta_1)\}\gamma_1^x \\ & + \quad \&c., \qquad \&c. \end{aligned}\right\} \quad (101)$$

By integration we get—

$$\begin{aligned} \int y\,dx = {} & Ax + B\beta^x + B_1\beta_1^x + B_2\beta_2^x + \&c. \\ & + \{C\sin(x\theta) + D\cos(x\theta)\}\gamma^x \\ & + \{C_1\sin(x\theta_1) + D_1\cos(x\theta_1)\}\gamma_1^x \\ & + \{C_2\sin(x\theta_2) + D_2\cos(x\theta_2)\}\gamma_2^x \\ & + \quad \&c., \qquad \&c., \qquad + \text{constant}; \end{aligned}$$

and taking this between the limits $x - \frac{1}{2}n$ and $x + \frac{1}{2}n$, and employing k, k_1, k_2, &c., and l, l_1, l_2, &c., as auxiliary letters, we have—

$$\left.\begin{aligned} & \left.\begin{aligned} k &= (\gamma^{\frac{1}{2}n} - \gamma^{-\frac{1}{2}n})\cos\tfrac{1}{2}(n\theta) \\ k_1 &= (\gamma_1^{\frac{1}{2}n} - \gamma_1^{-\frac{1}{2}n})\cos\tfrac{1}{2}(n\theta_1) \\ \&c., & \quad \&c. \end{aligned}\right\} \quad \left.\begin{aligned} l &= (\gamma^{\frac{1}{2}n} + \gamma^{-\frac{1}{2}n})\sin\tfrac{1}{2}(n\theta) \\ l_1 &= (\gamma_1^{\frac{1}{2}n} + \gamma_1^{-\frac{1}{2}n})\sin\tfrac{1}{2}(n\theta_1) \\ \&c., & \quad \&c. \end{aligned}\right\} \\ & S = An + B(\beta^{\frac{1}{2}n} - \beta^{-\frac{1}{2}n})\beta^x + B_1(\beta_1^{\frac{1}{2}n} - \beta_1^{-\frac{1}{2}n})\beta_1^x + \&c. \\ & \qquad + \{(Ck - Dl)\sin(x\theta) + (Dk + Cl)\cos(x\theta)\}\gamma^x \\ & \qquad + \{(C_1k_1 - D_1l_1)\sin(x\theta_1) + (D_1k_1 + C_1l_1)\cos(x\theta_1)\}\gamma_1^x \\ & \qquad + \qquad \&c., \qquad \&c. \end{aligned}\right\} \quad (102)$$

This is the expression for the sum S of any n terms taken in a group, the abscissa of the middle point of the group being x. It is of the same form as the expression for y in (101), so far as the variable x is concerned. To apply it to the graduation of a given irregular series, we assume certain groups of equal extent and equidistant, and denote the number of terms in each group by n_1, and the constant interval between the middle points of the groups by h. If we substitute n_1 for n in (102), and assign to x in succession the values corresponding to the middle points of the assumed groups, we shall obtain expressions for the sums S_1, S_2, S_3, &c., of the several groups. These sums will form a recurring series of the mth order if the number of groups assumed is the even number $2m$, in which case the constant A is to be omitted from the function altogether. But if an odd number, $2m + 1$, of groups is assumed, then A must be retained, and the differences—

$$(S_1 - An_1), \qquad (S_2 - An_1), \qquad (S_3 - An_1), \qquad \&c.,$$

will form a recurring series of the mth order. Let the m terms of the scale of relation be denoted by—

$$-A_1, \qquad -A_2, \qquad -A_3, \; \ldots\ldots\ldots\ldots \; -A_m$$

When the number of groups assumed is even, the numerical values of the scale-terms A_1, A_2, &c., are found from the m equations—

$$\left.\begin{aligned} A_1S_1 + A_2S_2 + A_3S_3 + \ldots\ldots + A_mS_m + S_{m+1} &= 0 \\ A_1S_2 + A_2S_3 + A_3S_4 + \ldots\ldots + A_mS_{m+1} + S_{m+2} &= 0 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots & \\ A_1S_m + A_2S_{m+1} + A_3S_{m+2} + \ldots\ldots + A_mS_{2m-1} + S_{2m} &= 0 \end{aligned}\right\} \quad (103)$$

But if the number of groups assumed is odd, we have the $m+1$ equations—

$$\left.\begin{array}{l} A_1(S_1-An_1)+A_2(S_2-An_1)+\cdots+A_m(S_m-An_1)+(S_{m+1}-An_1)=0 \\ A_1(S_2-An_1)+A_2(S_3-An_1)+\cdots+A_m(S_{m+1}-An_1)+S_{m+2}-An_1)=0 \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ A_1(S_{m+1}-An_1)+A_2(S_{m+2}-An_1)+\cdots+A_m(S_{2m}-An_1)+(S_{2m+1}-An_1)=0 \end{array}\right\}(104)$$

and $A\,n_1$ being eliminated by subtracting each equation from the succeeding one, there will be m equations remaining from which the values of the scale-terms may be found as before. Whether the number of groups assumed is $2\,m$ or $2\,m+1$, the equation of relation will be—

$$z^m+A_m\,z^{m-1}+A_{m-1}z^{m-2}+\cdots\cdots\cdots+A_2\,z+A_1=0$$

This numerical equation of the mth degree being solved, its real roots are the values of the constants β^h, $\beta_1{}^h$, $\beta_2{}^h$, &c. As for the imaginary roots, each pair of them are the roots of a quadratic factor of the equation of relation. These factors being found, let us denote them by—

$$\begin{array}{c} z^2+p\;z+q=0 \\ z^2+p_1\,z+q_1=0 \\ \&c., \&c. \end{array}$$

Then we shall have—

$$\left.\begin{array}{l} q=\gamma^{2h} \\ q_1=\gamma_1{}^{2h} \\ \&c., \&c. \end{array}\right\} \quad \left.\begin{array}{l} p=-2\gamma^h\cos(h\,\theta) \\ p_1=-2\gamma_1{}^h\cos(h\,\theta_1) \\ \&c., \quad \&c. \end{array}\right\} \qquad (105)$$

and thus the values of the constants γ, γ_1, γ_2, &c., and of the constant arcs θ, θ_1, θ_2, &c., become known. Substituting them and the values of β, β_1, β_2, &c., in the general formula (102), and assigning to n the numerical value of n_1, and to S the successive numerical values of S_1, S_2, &c., and to x the corresponding values for the middle points of the groups, we shall have a system of equations which, besides the constants A, B, B_1, B_2, &c., C, C_1, C_2, &c., and D, D_1, D_2, &c., contains only numerical quantities. These constants will be m or $m+1$ in number, according as there are $2\,m$ or $2\,m+1$ assumed groups. We shall only have to form as many equations as there are constants, and then the values of the constants can always be found.

Having thus completed the determination of all the constants in formula (102), we are enabled to interpolate the sum S of any group of n terms in the graduated series; and if we take—

$$n=1, \qquad\qquad S=u$$

the equation of the series may be reduced to the simple form—

$$\left.\begin{array}{l} u=A+b\,\beta^x+b_1\,\beta_1{}^x+b_2\,\beta_2{}^x+\&c., \\ \quad +\{c\sin(x\,\theta)+d\cos(x\,\theta)\}\,\gamma^x \\ \quad +\{c_1\sin(x\,\theta_1)+d_1\cos(x\,\theta_1)\}\,\gamma_1{}^x \\ \quad + \qquad \&c., \qquad \&c. \end{array}\right\}(106)$$

The sums of the terms in the $2m$ or $2m+1$ assumed groups will be the same as in the given series. If the number of groups assumed was $2m$, the graduated series will be recurrent, and of the mth order; if the

number of groups was $2m+1$, the series will be of the $(m+1)$th order, but after the constant A has been subtracted from each term, the remainders will form a series of the mth order.

We will now make an application of this method to the graduation of series (f) in Table II of the previous memoir, in order to illustrate the working of the formulas, but without any design of specially recommending the method for adjusting mortality-tables. Let us assume six consecutive groups of equal extent, so as to have—

$$m = 3, \qquad n_1 = h = 15$$

The sums of the terms in these six groups are—

$$S_1 = 7.8522 \qquad S_3 = 21.069 \qquad S_5 = 182.02$$
$$S_2 = 12.255 \qquad S_4 = 54.573 \qquad S_6 = 446.84$$

Substituting these values in the equations (103), we have three equations from which we find the three-scale terms—

$$A_1 = -27.799, \qquad A_2 = 24.863, \qquad A_3 = -6.6914$$

and the equation of relation therefore is—

$$z^3 - 6.6914\, z^2 + 24.863\, z - 27.799 = 0$$

This has only one real root,

$$z = \beta^{15} = 1.6960;$$

and consequently we have $\beta = 1.0358$. Dividing the equation of relation by—

$$z - 1.6960 = 0$$

we get the quadratic factor—

$$z^2 - 4.9954\, z + 16.391 = 0$$

which contains the pair of imaginary roots. Hence, by the formulas (105) we have—

$$16.391 = \gamma^{30}, \qquad 4.9954 = 2\,\gamma^{15} \cos 15\theta$$

which give for the values of the two constants—

$$\gamma = 1.0977, \qquad \theta = 3^\circ\, 27'\, 37''.8$$

Now, substituting the values of β, γ, and θ in (102), and taking—

$$n = n_1 = 15, \qquad A = 0$$

we find—

$$k = 1.3623, \qquad l = 1.0981$$

and assigning to S in succession the values of S_4, S_5, and S_6, and to x the corresponding values $\frac{15}{2}$, $\frac{45}{2}$, and $\frac{75}{2}$, we get the three equations—

$$54.573 = .69599\, B + 3.1862\, C + 1.4977\, D$$
$$182.02 = 1.1804\, B + 12.731\, C - 6.4117\, D$$
$$446.84 = 2.0019\, B + 11.368\, C - 56.579\, D$$

from which the values of the three remaining constants are found to be—

$$B = 57.520, \qquad C = 6.6876, \qquad D = -4.5182$$

We have thus determined all the constants of formula (102) which are required for the case in hand, and are enabled to find by interpolation

the sum S of any group of n terms, the abscissa of whose middle point is x. If we take—

$$n = 1, \qquad\qquad S = u$$

we shall have—

$$k = .093216, \qquad\qquad l = .060463$$

and consequently—

$$u = 2.0259\ \beta^x + \{.89658 \sin (x\,\theta) - .01682 \cos (x\,\theta)\}\ \gamma^x$$

which may be transformed into—

$$u = 2.0259\,\beta^x + .89675 \sin (x\,\theta - 1^\circ\ 4'\ 29'')\,\gamma^x$$

and this is the equation of the graduated series, the values of β, γ, and θ being, as already stated,

$$\beta = 1.0358, \qquad \gamma = 1.0977, \qquad \theta = 3^\circ\ 27'\ 37''.8$$

When the values $-\frac{1}{2}$, $+\frac{1}{2}$, $+\frac{3}{2}$, &c., are successively assigned to x, the resulting values of u will be the adjusted terms for the ages 54, 55, 56, &c. The whole series is shown in the accompanying table. The sums of the terms in the six assumed groups are equal to those in the given series (f).

Age.	u	Age.	u	Age.	u	Age.	u	Age.	u
10	.4167	28	.7210	46	1.2958	64	3.977	82	16.949
11	.4304	29	.7421	47	1.3531	65	4.310	83	18.197
12	.4445	30	.7637	48	1.4158	66	4.676	84	19.497
13	.4589	31	.7861	49	1.4846	67	5.077	85	20.84
14	.4737	32	.8092	50	1.5601	68	5.516	86	22.23
15	.4889	33	.8331	51	1.6434	69	5.995	87	23.64
16	.5044	34	.8580	52	1.7352	70	6.517	88	25.07
17	.5202	35	.8840	53	1.8366	71	7.085	89	26.51
18	.5365	36	.9110	54	1.9486	72	7.701	90	27.94
19	.5531	37	.9395	55	2.073	73	8.367	91	29.33
20	.5701	38	.9695	56	2.210	74	9.087	92	30.67
21	.5875	39	1.0011	57	2.362	75	9.862	93	31.93
22	.6052	40	1.0348	58	2.530	76	10.695	94	33.07
23	.6234	41	1.0706	59	2.715	77	11.586	95	34.06
24	.6420	42	1.1091	60	2.921	78	12.538	96	34.86
25	.6610	43	1.1503	61	3.147	79	13.550	97	35.41
26	.6805	44	1.1950	62	3.397	80	14.624	98	35.67
27	.7005	45	1.2432	63	3.673	81	15.758	99	35.57

When we assume only three groups, S_1, S_2, and S_3, in a given series, the three constants will be—

$$\left.\begin{aligned}
\beta^h &= \left(\frac{S_3 - S_2}{S_2 - S_1}\right) \\
A &= \frac{1}{n_1}\left\{ S_2 - \left(\frac{S_3 - S_2}{\beta^h - 1}\right)\right\} \\
B &= \frac{S_3 - S_2}{(\beta^h - 1)\,(\beta^{\frac{1}{2}n_1} - \beta^{-\frac{1}{2}n_1})}
\end{aligned}\right\} \quad (107)$$

These are the same as in (67), except that the origin of co-ordinates is now placed at the middle of the series.

The foregoing processes will serve for the purpose of ordinary interpolation from single terms, if we denote the given terms by S_1, S_2, &c., and take—

$$n = n_1 = h = 1$$

This corresponds to what has already been noticed in connection with algebraic and circular functions.

A great drawback to the utility of this whole method of interpolation is that the equation of relation will sometimes be found to have one or more negative roots, in which case the method fails, although it may succeed if we assume a different set of groups. It is evident that if we have, for instance, β^h negative, then β will be either negative or imaginary; and when values differing from each other by unity are successively assigned to x in βx, the resulting values will be either alternately positive and negative, or some of them will be imaginary, and in either case the series becomes useless for purposes of interpolation.

It should also be observed that in the process we have followed, the roots of the equation of relation are all supposed to be unequal. If any of them were equal, it would involve a change in the form of the function. For instance, if there were m real roots equal to β^h, they would together correspond to a term in the function of the form—

$$b\,(1 + a_1\,x + a_2\,x^2 + \; . \; . \; . \; . \; . \; . \; . \; . \; + a_{m-1}\,x^{m-1})\,\beta^x$$

while, if there were m equal pairs of imaginary roots, they would be represented in the function by a term of the form

$$(1 + a_1\,x + a_2\,x^2 + \; . \; . \; . \; . \; . \; . \; + a_{m-1}\,x^{m-1})\left\{c \sin(x\,\theta) + d \cos(x\,\theta)\right\}\gamma^x$$

But the case of equal roots is a special one, which can hardly be expected to occur when the equation of relation has been constructed from an irregular series of numbers derived from observation; so that, for practical purposes, it is not necessary to consider this branch of the subject any further.

We see from the above that an algebraic and entire polynomial is a special case under the class of recurrent functions, the case, namely, in which all the roots of the equation of relation are equal to unity, so as to make $\beta = 1$, and consequently $\beta x = 1$. That any series of algebraic form is recurrent, is evident when we consider, for example, a series of the third or some lower order. To say that any five consecutive terms in it are characterized by the property—

$$\Delta_4 = 6\,u_3 - 4\,(u_2 + u_4) + (u_1 + u_5) = 0$$

is merely saying that any term u_5 can be obtained from the four terms next preceding it by multiplying them severally by the scale of relation—

$$-\,A_1 = -\,1, \qquad -\,A_2 = 4, \qquad -\,A_3 = -\,6, \qquad -\,A_4 = 4$$

and adding the products together. Upon this recurrent property depends the construction of all the adjustment-formulas of our second method. They, however, are not the only ones which can exist under the general form (88), for we can assign any real values we please to the weights l_0, l_1, l_2, &c., and the formula will still apply to some transcendental series. For instance, we have seen that the formula—

$$u_3 = \frac{1}{k + 6}\left\{k\,u_3 + 4\,(u_2 + u_4) - (u_1 + u_5)\right\}$$

in which k is any arbitrary number, will give exact results when applied to a series of the third or any lower order; that is, to any equidistant values of the function—

$$u = A + B\,x + C\,x^2 + D\,x^3$$

Similarly, the formula—

$$u_3 = \frac{1}{k+8}\left\{ k u_3 + 5\,(u_2 + u_4) - (u_1 + u_5) \right\}$$

will give exact results for any series of equidistant values of the function—

$$u = A + Bx + C\left(\frac{3+\sqrt{5}}{2}\right)^x + D\left(\frac{3-\sqrt{5}}{2}\right)^x$$

provided that these values are taken at intervals equal to unity. So, also—

$$u_3 = \frac{1}{k+4}\left\{ k\, u_3 + 3\,(u_2 + u_4) - (u_1 + u_5) \right\}$$

will be exact for equidistant values of—

$$u = A + Bx + C\sin\frac{\pi x}{3} + D\cos\frac{\pi x}{3}$$

taken at intervals of unity. But these two last adjustment-formulas will not apply to series of values of the functions taken at any equal intervals other than unity, and therein lies their inferiority to the formulas of our second method, which apply alike to all equidistant values of the algebraic function independently of the magnitude of the interval.

We may notice further that the circular function—

$$u = B_1 \sin(x\theta) + C_1 \cos(x\theta) + B_2 \sin 2\,(x\theta) + C_2 \cos 2\,(x\theta) + \ldots\ldots$$
$$\ldots\ldots + B_m \sin m\,(x\theta) + C_m \cos m\,(x\theta)$$

is a recurring function of the $2m$th order, whose equation of relation has no real roots, but has m pairs of imaginary ones, such as to make γ, γ_1, γ_2, &c., all equal to unity, the equation of relation being a reciprocal equation. The property demonstrated by Airy, in connection with a process for smoothing down the irregularities of series of circular form, in the Transactions of the Royal Society for 1870, is a consequence of this recurrent character of the function. If a constant term A were added to the function, the series would be raised to the $(2m+1)$th order, the constant being represented in the equation of relation by a single real root equal to unity.

APRIL, 1874.

APPENDIX.

Additions to Table III.

When these adjustment-formulas are to include a considerable number of terms, the easiest way to construct them will be to regard the weights, in their fractional form, as ordinates to a curve of the tenth degree, and to take the weight of the middle term as the axis of Y, so that the curve will be symmetrical on either side of this axis, and its equation, containing only even powers of x, may be written—

$$y = A + B\,x^2 + C\,x^4 + D\,x^6 + E\,x^8 + F\,x^{10}$$

Suppose, for instance, that we wish to find the 23-term formula. Let

the constant interval between the weights be taken as the unit of x. Schiaparelli's two conditions give the two equations—

$$23\,A + 2\,\{(11^2)\,B + (11^4)\,C + (11^6)\,D + (11^8)\,E + (11^{10})\,F\} = 1$$
$$(11^2)\,A + (11^4)\,B + (11^6)\,C + (11^8)\,D + (11^{10})\,E + (11^{12})\,F = 0$$

where the notation used is—

$$(11^m) = 1^m + 2^m + 3^m + \ldots\ldots\ldots + 11^m$$

Since the curve passes through the positions of the eight nearest zero-weights, we have also these four equations:

$$A + 12^2\,B + 12^4\,C + 12^6\,D + 12^8\,E + 12^{10}\,F = 0$$
$$A + 13^2\,B + 13^4\,C + 13^6\,D + 13^8\,E + 13^{10}\,F = 0$$
$$A + 14^2\,B + 14^4\,C + 14^6\,D + 14^8\,E + 14^{10}\,F = 0$$
$$A + 15^2\,B + 15^4\,C + 15^6\,D + 15^8\,E + 15^{10}\,F = 0$$

This makes six equations in all, enabling us to compute the numerical values of the six constants, A, B, &c., in the equation of the curve, after which, by assigning to x in succession the values 0, 1, 2, 3, &c., we get values of y which are the weights of the adjustment-formula sought. Commencing with the middle term, they are—

$$\left.\begin{matrix} .1534 & .1463 & .1262 & .0969 & .0635 & .0317 & .0065 \\ & & -.0092 & -.0151 & -.0133 & -.0077 & -.0025 \end{matrix}\right\} \quad (108)$$

In a similar way, the weights of the 25-term formula have been found to be—

$$\left.\begin{matrix} .1424 & .1368 & .1205 & .0962 & .0678 & .0395 & .0151 \\ & -.0024 & -.0119 & -.0140 & -.0110 & -.0060 & -.0018 \end{matrix}\right\} \quad (109)$$

If it were desirable, there would be no great difficulty in extending the series of formulas still farther.

In each of the foregoing cases, if the greatest nicety of adjustment is required, the weights ought to include as many as four places of decimals, because, if the fourth figure is neglected, the error-ratios $\frac{\varepsilon'}{\varepsilon}$ are found to be materially increased. These ratios, as computed by formula (92), are respectively .00124 and .00091 when four places are retained, but with only three places they are increased to .00191 and .00197 respectively.

On the other hand, it is found that the error-ratios for the 5, 7, and 9-term formulas of Table III are not materially altered by dropping the third decimal place, so that the first part of that table might as well stand thus:

	5	7	9
l_0	.56	.42	.34
l_1	.29	.29	.27
l_2	−.07	.05	.11
l_3		−.05	−.02
l_4			−.03
$\frac{\varepsilon'}{\varepsilon}$	.23	.080	.038

To secure the greatest practical facility in making adjustments, no more figures should be used than are really necessary.

AUGUST, 1874.

ERRATA.

At age 54 of column (a), in Table I, (Smithsonian Report of 1871, p. 287,) for 1.80 read 1.43. The error occurs in the original table in the Massachusetts Report.

In the foot-note at page 317 of the Smithsonian Report of 1871, for *Lionville's* read *Liouville's*.

ETHNOLOGY.

REMARKS ON THE KJÖKKEN-MÖDDINGS ON THE NORTHWEST COAST OF AMERICA.

By Paul Schumacher.

During my excursions along the coast, from Crescent City (latitude 41° 44′ 30″) to Rogue River, (latitude 42° 25′,) I found numerous veidences of Indians of a past time who occupied houses.

Near a river, or in places on the coast where there are groups of rocks stretching out frequently for miles into the ocean, there are almost cer tain to be found on every eminence which would serve as a look-out to prevent sudden attacks, traces of former dwellings.

As in certain seasons the rivers yield vast quantities of trout and salmon, so also do the rocks supply edible shell-fish, which principally adhere in clusters to the rocks washed by the ocean; in the shallow water on the shores, in the tangled masses of sea-plants, all kind of fish deposit their spawn and search for food, while the sea-lion and its relation, the seal, disport themselves among the breakers, alternately fishing and sunning themselves on the rocks. Shell-heaps, bones of sea-lions, deer, and bear, chiefly mark the localities where these ancient dwellings have formerly existed. These remains are in layers, which become more and more indistinct as their age and depth increase, until the whole is reduced to a dark and ash-like earth, in which stone implements alone remain distinguishable as evidence of a prehistoric population.

At the suggestion of the Smithsonian Institution, I visited the shell-heaps, which to the present Indians are known by the names of Chīt, (now Chetko;) Nat-ĕ-nēt, (Lone Ranch;) Khŭst-ĕ-nēt, (Hustenate;) Chĕtl-ĕ-shĭn, (Big Rock, now Crook's Point,) and found there many kinds of implements, some of which were slightly broken, but most of them were only fragments.

Arrow and spear heads were found in great numbers and variety, besides pestles, knives, pipes, wedges, and other articles, the use of which I have not yet been able to ascertain.

In the following statement I give a list of the objects which I have presented to the National Museum, adding such remarks as appear to me necessary.

ARROW-HEADS.

The peculiarity of the shape of the arrow as well as spear heads requires a certain classification, and, having divided them into sets, I here briefly mention the following kinds:

Nos. 1 to 32.—With long barbs and with projections.

Nos. 33 to 45.—With short barbs and with projections.

Nos. 46 to 47.—Without barbs and with projections.

Nos. 48 to 94.—With barbs and without projections.

(Nos. 48 to 80.) *a.* Long arrow-heads.

(Nos. 81 to 94.) *b.* Short arrow-heads.

Nos. 95 to 96.—Of glass; were made in my presence by a Klamath Indian, to explain the mode of manufacturing them.

SPEAR-HEADS.

Nos. 97 to 101.—Of a very clearly-defined shape, without barbs, but with a projection. The pointed teeth show them to have been dangerous weapons.

No. 123.—Same species, but blunt.

Nos. 102 to 122.—With short barbs and with projection.

Nos. 124 to 177.—Leaf-shaped, without barbs or projections.

Nos. 178 to 193.—With barbs, but without projections. The circumstance that arrow as well as spear heads without projections were fastened to the wooden shaft with sinews, holding them only long enough to pierce the object, but detaching them when withdrawn, must lead us to the conclusion that such implements were only used against enemies, as making the most dangerous wounds. The well-fastened heads with projections were better suited for hunting; not only are they preserved for future use, but the adhering shaft also impedes the flight of the animal.

KNIVES.

Nos. 201 to 204.—Semi-oval.

Nos. 205 to 207.—Lancet-shaped.

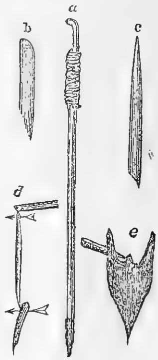
ADZES.

Nos. 196 to 200 and 213 to 214.—Of somewhat differing shapes; No. 198 excelling by its neatly-chipped edge.

The manufacture of arrow and spear heads, knives, and adzes, and in general of all such implements as are made of flint, obsidian, jasper, &c., and which have sharp points and edges—if we suppose that the ancient people were a kindred race with the present Klamath Indians—may be described as follows: A piece of one of the above-mentioned stones, which breaks sharp-cornered, and with a conchoidal fracture, is heated in the fire, and then rapidly cooled, after which it is struck on

the break-edge, by which means it is split into flakes. To such a flake a suitable rough shape is given by striking it with a tool, such as may be seen in Nos. 271 to 273, in which state the real manufacture commences. For this purpose the tools are used which I have exhibited in the accompanying sketch, (Fig. B.) A piece of bone is fastened to a wooden shaft 1½ feet in length, (*a*,) the working point of which (*b*) is crooked and raised to an edge. The applications to be made of this instrument are shown with the two principal angles in *d*, only a pushing force being employed during the time. To guide the instrument with a steady hand the handle is held between the arm and breast, while the point, with but little play-room, assisted by the thumb, works on the edge of the flake, which again is held, for greater safety, in a piece of deerskin. After the two sides have been worked down to a point, then another instrument is required, (*c*,) with which the barbs and projections are broken out, (*e*.) This is a needle or awl, of about three inches in length, (Nos. 233 to 235,) and by a pushing motion the desired pieces are broken out in the same manner as with the first-mentioned tool.

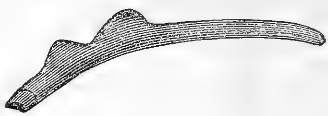
Fig. B.



It would be impossible to produce a more delicately-formed arrow-head (as, for instance, No. 1) by hammering; and a short trial of the above-described method will prove the advantage of this method of operating.

No. 208—Is an implement of bone, which, together with skull No. 289, clay-pipe No. 242, and implement No. 269, I found in a grave in Chetko. I saw a similar piece (Fig. E) in Crescent City, made of dark stone and nicely polished, which was found in Happy Camp, at a depth of 40 feet below the surface.

Fig. E.



No. 209.—Amulet; probably worn as an ornament around the neck. Although in shape it is similar to a sinker, it is too carefully made and ornamented, as well as not heavy enough, to have been used for that purpose.

Nos. 210 to 287.—Wedges.

Nos. 211 to 212.—Spades.

Nos. 215 to 223.—Drills.

No. 224.—Rubbing-pestle.

Nos. 225 to 226.—Probably drills.

Nos. 227 to 229.—Unknown.

Nos. 230 to 232.—Drills of bone.

Nos. 233 to 235.—Awls used to make arrow-heads, (Fig. B, *c*.)

No. 236.—Unknown.

No. 237.—Ornament worn through the septum of the nose; prettily made and ornamented.

No. 238.—Unknown.

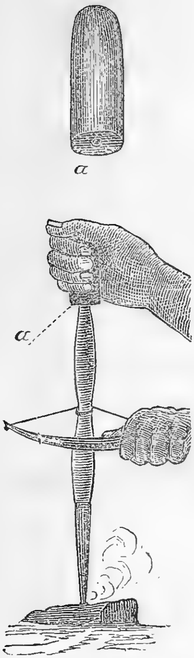
No. 239.—A fragment, of which a great number occur on the shell-heaps where quarries appear to have existed.

No. 240.—Unknown.

No. 241.—Spoon of bone, which was found in a newer layer.

Nos. 242, 243, 288.—Pipes; the first one of clay, which I found in a grave with Nos. 208, 269, and 289; the second one (No. 243) is of talc; probably a failure, and, therefore, not completed, but exhibiting the manner of manufacturing. The boring of the tube was evidently done with an instrument, and, according to the explanation of an Indian, this tool is identical with a bow-drill, (Fig. F,) while the larger opening, in which it is intended to place the tobacco, was hollowed out in the usual manner. The other pipe (No. 288) appears to be an attempt to work in clay.

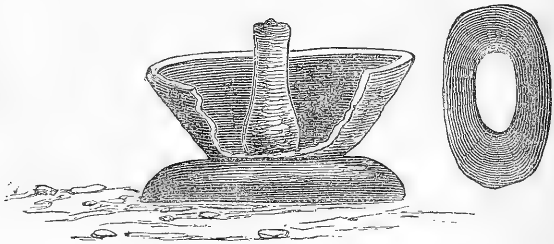
Fig. F.



Nos. 244 to 249.—Sinkers. I am not positive whether No. 209 (also No. 244) was used as a sinker.

Nos. 250 to 259.—Pestles. These instruments are of different shapes, and are frequently found. But, because mortars are found but rarely, we must suppose that in early times, as at the present, the pestles were used mostly to crush acorns on a flat stone, around which was placed a low, bottomless basket, of about 1½ feet in diameter, into which were thrown the acorns to be crushed, (Fig. C.)

Fig. C.



The slender pestles (Nos. 250 to 252) I think may also have been used as war-clubs, in favor of which supposition is their shape, and also the fact that they have been frequently broken by a side-pressure.

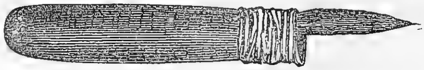
Nos. 260 to 262.—Objects of the uses of which I have no very decided opinion. They may have been used as hammers to break shells of acorns.

No. 263.—Used to rub colors.

Nos. 264 to 266.—Probably used to rub skins. The latter are not finished yet, thus showing the process of making them. But of the use of No. 266 I am not sure.

No. 268.—The handle of a tool for hollowing out canoes, which is fully shown in the accompanying drawing, (Fig D.)

Fig. D.



No. 269.—The upper part of a handle belonging to a tool like No. 268. I found it in the excavation with Nos. 208, 242, and 289.

No. 270.—Approaches in shape to an ax, and appears to have been broken in use.

Nos. 271 to 281.—Stones as shaped by nature, which might easily mislead the collector. But if the undisturbed position is regarded in which they were found, we soon come to the conclusion that no Indian hand gave them this form, but that it was the sand, driven by heavy winds, which polishes all exposed objects. I also found such stones on bare sand-hills, but mainly on the hard yellow ground of Crook Point, on both sides of which drift-sand is abundant, and where the continual northwest wind during summer and violent southwesterly storms in the winter drive heavy masses of sand before them. There these stones either stick in the loamy soil, their surface only being exposed, (No. 275;) or they lie in a steep bank, so that only one edge projects out above the surface, (No. 276;) and again others in such a position that the sand can get at them on all sides, (Nos. 274 and 277.)

Nos. 282 to 283.—Unknown.

Nos. 284 and 285.—Perhaps spades.

No. 286.—Evidently a whetstone.

Nos. 289 to 291.—Skulls, the measurements of which are as follows:

Number of skull.	Distance from root of nose over top of head to position of foramen magnum.	From orifice of ear— Over forehead and occiput.	From orifice of ear— Over top of head.	From orifice of ear— Over occiput.	Periphery from eyebrow to occipital crest.	Found at—
	Centimeters.	*Centimeters.*	*Centimeters.*	*Centimeters.*	*Centimeters.*	
291	37	50	33.5	29	25	Pistol River.
289	38	53	35.0	32	30	Chetko.
Not sent	34.5	49	32.25	28	24.75	Do.
290	35.25	51	31.25	31	27.5	Big Lagoon.

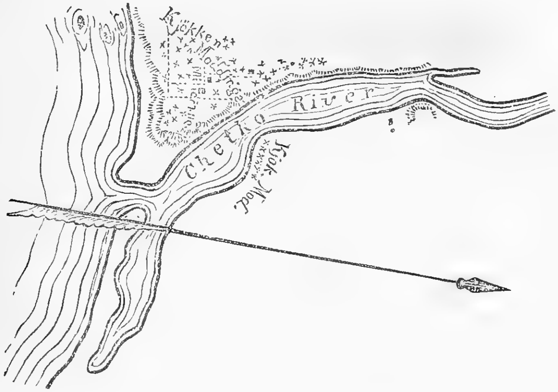
The following shells, the names of which Mr. Dall kindly ascertained and fixed for me, I present as the characteristic species which constitute and are found in the Kjökken-Möddings. The relative percentage I approximate at 0.7 *Mytilus californianus;* 0.2 *Tapes staminea;* and 0.1 of the remaining ones, among which *Machæra patula* and *Bulimus* and *Purpuca lactuca* are predominant.

REMARKS ON THE CHARACTERISTICS OF THE DESERTED SETTLEMENTS ON WHICH THESE OBJECTS WERE FOUND.

Chit, now Chetko, (*Map G.*)—On the elevated right bank of the Chetko River, near its mouth, there are extensive beds of bleached shells, fish-

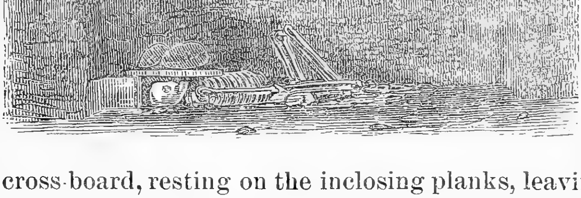
bones, and those of animals. The layers reach probably to a great depth, but I only had opportunity to measure to a depth of 10 feet,

Map G.



which was at a place where a settler named Miller was digging a foundation for a house. My visits to this place were only casual, for my duties allowed me but little time to explore this interesting locality. But on one occasion I found time to search for graves, and in this was guided by the following circumstances: In the first place, I made sure of a locality on which, in former times, huts had existed, which I soon recognized by a slight circular depression. In this locality these stretched along in a pretty regular line to a point where the otherwise level bank rises in a steep ascent. As these graves are found only a few steps from the remains of the habitations, I had not long to search, and soon found a wooden inclosure which contained a skeleton. I found the grave to be 3½ feet deep, inclosed on the sides with split redwood planks, trees of which are found on the shores and river-banks as drift-wood. Between these was laid the skeleton, with legs drawn up; the latter encircled by the outstretched arms, in such a manner that the bones of the hands were mixed up with those of the feet. *It was lying on the back, face up, and turned toward the southwest,* (Fig. G, *b.*) Over the

Fig. G, b.



head was a cross-board, resting on the inclosing planks, leaving only one inch of clear space between it and the skull. The cross-board was weighted with heavy stones, which had been obtained on the sea-shore. The other part of the skeleton was unprotected, and closely packed in the soil.

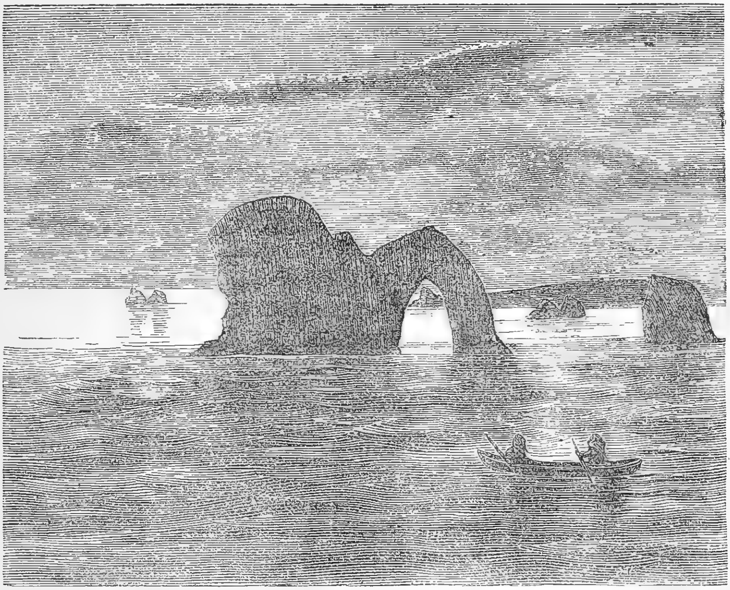
About three feet farther on I found a second grave similarly formed with also a skeleton in exactly the same position, with the exception that the drawn-up knees had been pressed toward the right side, and that the head-board, being decayed, had fallen down so that the heavy stones were resting on the skull. The mouth was wide open, with a round stone sticking in it, which might have been pressed in when the head-board fell. Close to the side of the first skeleton lay an implement of bone, (No. 208,) of which some few pieces were lost, either before interment or through the hasty manner in which the search was made, as I did not wish to awaken the suspicion of the natives, and, furthermore, time was precious to me. I found nothing worth mentioning in the soil about the skeletons. It was mixed with broken stones, which appeared to have been exposed to fire, such as I have found frequently below the surface, mixed also with pieces of flint, bones, shells, &c. About one foot above the skeleton I found the handle, No. 269, and about the same distance below the surface the fragment of clay-pipe No. 242; but it appeared to me that the two last-mentioned ones had been deposited in this place accidentally. I do not share the opinion that the implements found in the grave of the former owner of the soil had been purposely broken, as I found in well-preserved graves different objects in a sound condition, mingled with the broken implements; I observed the position of the latter, and always found the fitting pieces together, from which it became evident that the pressure of the earth or other accident had caused their breakage after they had been buried. I think that at this place numerous other skeletons might be found with little trouble.

Here I must further remark that on the Bald Mountain, which is on the left bank of the Chetko River, about five miles from its mouth, and which is about 3,000 feet high—being the highest mountain in this vicinity—there are said to be various kinds of stone implements, among which are those which, in former times, are reported to have been used by a medicine-man in his superstitious rites. I give the tale for what it may be worth.

Năt ĕ-nĕtĕn, (*Lone Ranch.*)—If we follow the coast-trail three miles in a northerly direction, we come to a side-trail where a way-mark points to Lone Ranch, which is about six miles from Chetko. Mr. Cresswell is the owner of this land on which the *débris* of the former inhabitants is lying in great quantities. At a measured depth of 28 feet I saw gigantic bones of different kinds of animals. In the lower layers the shells and bones are completely decayed, and have been changed into a dark ash-like soil. There is much of interest here, but my two visits were of short duration, and I was prevented from making measurements of bones and skulls as I should like to have done. These heaps are the oldest that I have seen. The soil is too sandy and too dry for even a shrub to grow on the large hill, which is near the house. Opposite the creek are the depressions marking the sites of former huts still plainly visible, but the quantity of shells is small. About one mile

southward there are other shell-heaps on a small sand-hill. (This is the locality where the fine obsidian knives were found, which are in a private collection at this place.)

Fig. H.



Chĕtl-ĕ-shĭn, (*Big Rock, now Crook's Point, Figure H.*)—About three miles from the mouth of Pistol River and six miles from the prominent Cape Sebastian southerly, there is a flat point known as Crook's Point. Southwest of this is a rock, separated from a group, which is made prominent by forming a very picturesque arch. After this rock the deserted homestead of the Indians was named. If from this point we follow the bluff on the left side, (*i. e.*, northward,) we find flint splinters and shell and bone remains in large quantities up to a place where a small creek crosses the path; thence the *débris* is found in single heaps along the sands toward Pistol River. In a place where the latter makes a strong eddy, there has been an important *rancheria*, and there I found the finest arrow-heads. A little farther up the river, between the sand-hills, there are yet found remains of the "fort" of 1856, of the time of the Rogue River war. Between Crook's Point and this place it was evident that battles had been fought; for along this distance the finest assortment of arrow and spear heads was found.

If we now cross the river and mount the plateau of the right bank, we find, immediately in the angle formed by the bend of the river, where in former times was a settlement, excavations, which stretch for 100 yards beyond Dolan's house, and of which the remains then suddenly cease, appearing again in small numbers at a place near the cape.

South from Crook's Point lies Khust-ĕ-nĕtĕ, a deposit of great extent, but I had not even time to give it the slightest examination. Eight miles

north of the cape, at the mouth of Rogue River, there is another important deposit, which I also could not visit for want of time.

The skull, No. 290, I found near Big Lagoon, nine miles north from Trinidad. Riding past the nearly deserted camp of the Big Lagoon Indians, I saw the skull projecting from the bluff and picked it up. The ribs and skull were exposed, and the position of the skeleton was recognizable. It lay on its back, face upward, and turned northeastward. Besides this, I found three well-preserved skulls lying on the surface, but I had no room for their transportation.

Had I the means to explore the above-mentioned Kjökken-Möddings for say two months, following them up as far as Port Orford, I am certain that material enough could be found to fill a cabinet.

PLACES WHERE THE DIFFERENT IMPLEMENTS WERE FOUND.

Chetko.—Nos. 208, 242, 247 to 249, 259, 269, 289.

Lone Ranch.—Nos. 234, 236, 250 to 252, 255.

Crook's Point.—Nos. 97 to 99, 105 to 107, 190 to 205, 210 to 214, 216 to 229, 240, 243, 246, 260, 262, 263 to 268, 270 to 287.

Near Old Fort of 1856.—Nos. 102 to 104, 108 to 112, 118 to 120, 127 to 135, 209, 215, 230 to 233, 237, 241, 244, 245, 261, 291.

Dolan.—Nos. 100, 101, 113 to 117, 121 to 126, 136 to 189, 206, 207. 235, 238, 288. (Examine 165.)

Big Lagoon.—Nos. 253, 254, 256 to 258, 290.

Old Fort and Crook's Point.—Nos. 1 to 94.

NAMES OF SHELLS.

No. 292. *Mytilus californianus*, Conr.
293. *Tapes staminea.*
294. *Cardium Nuttallii*, Conr.
295. *Hinites giganteus*, Gray.
296. *Standella Californica.*
297. *Pholadidea penita.*
298. *Purpura lactuca.*
299. *Purpura septentrionalis.*
300. *Petricola carditoides*, Conr.
301. *Machæra patula.*
302. *Bulimus.*

(Pursh, fol. 1, page 141, &c.)

ON A GRAMMAR AND DICTIONARY OF THE CARIB OR KARIF LANGUAGE, WITH SOME ACCOUNT OF THE PEOPLE BY WHOM IT IS SPOKEN.

By Dr. C. H. Berendt.

The Rev. Alexander Henderson (Belize, British Honduras) has sent me the grammar and dictionary of the Carib, or Karif, language, of which I have written you before, and I have the pleasure to present it, in the author's name, to the Institution, requesting that your acknowledgment of receipt may be sent to him. He expects to receive a hundred copies for himself, if it is published by the Smithsonian.

This language is spoken by the descendants of the Indians and half-breeds brought by the British government in 1796 from the island of Saint Vincent to Raatan, whence they soon spread over the coast of Honduras and the British settlement in Yucatan. Their actual number is estimated at about ten thousand, living in larger or smaller communities, and working generally in the wood-cuttings of that coast. Though nominally Christians, they still retain some of their ancient customs, and are particularly adverse to monogamy.

These Caribs, or Karifs, as Mr. Henderson spells the name, and according to the mode in which they themselves pronounce it, (Karifune,) were of the original West Indian Carib stock, but had become mixed with negroes from an African slaver, wrecked on the coast of Saint Vincent. They afterward were distinguished as red (or yellow) and black Caribs, according to their similarity in color to one or the other parental race. Their island having been alternately under French and British dominion, the language of the natives became mixed with many French and some English elements. It is asserted that it contains also some African admixture. After their arrival on the Honduras coast, these Caribs have further adopted a number of Spanish words, and it is likely that a few words of their actual language, corresponding with their equivalents in Central-American languages, have been introduced in the same manner.

Of this language, very little has become known. Colonel Galindo has given a brief vocabulary (seventeen words, and the numerals from one to ten) in the Journal of the Royal Geographical Society, (1833,) and the author of the present work has printed in Edinburgh (1847) a translation of the Gospel of Matthew. His missionary life among those people enabled him to compose the grammar and dictionary of that language, which is of interest, not only because it is spoken by a useful and numerous tribe of our continent, but particularly as an object for the study of the transitions in languages which are influenced by admixture from other languages of an entirely different character. For these reasons I believe that the publication of this work will be found advisable, though in its present shape it is not exactly fit for that purpose. It is but natural that forty years of life in the tropics show their influence in a septegenarian. A certain prolixity and some want of order in the arrangement must be attributed to this cause, but it does not impair

the intrinsic value of the material. If it were decided to print this work, I would suggest a re-arrangement, bringing under the same headings those articles that naturally belong together, but are scattered here through the whole work, and leaving out those numerous grammatical forms, which unnecessarily swell the dictionary, as they result from the rules and examples given in the grammar. I have made such new arrangement for my own use, and shall prepare a copy for the Institution, if such be desired.

With regard to the preface, (pp. 339 and 340 of the eighth volume,) I may be permitted to say that the author's conjecture concerning a Maya-origin of the Carib-tribe is not borne out, either by history or by philological comparison. It is this, a pet-theory of later date, which has even induced the author to confound the Maya-population north of Belize with the Caribs living southward of the same place. He writes to me himself that those Karifs, seventy-five miles north of Belize, "speak the Maya-language," and that they discard the name "Caribs," while his dictionary, which was certainly made among the Caribs southward of Belize, has the words *Karifune* for Carib, and *Kariniazu* for Red Caribs.

THE MOUND-BUILDERS AND PLATYCNEMISM IN MICHIGAN.

By Henry Gillman.

Throughout the region of the Great Lakes occur many of the most interesting relics of the race known as the "Mound-builders." Even as far north as the State of Michigan, so large a portion of the boundaries along the shore-line of the lakes and rivers of the region abounds in the presence of those remains as to be a subject of wonder to all who have investigated the subject. From the west end of Lake Erie, along the banks of the Detroit River, the shores of Lake Saint Clair, and the coasts of Lakes Huron and Michigan, through the passage of the Saint Mary's River, to Lake Superior, including isolated Isle Royal, near its northern limits, the remains of the mysterious people, who resided here hundreds of years ago, may be traced.

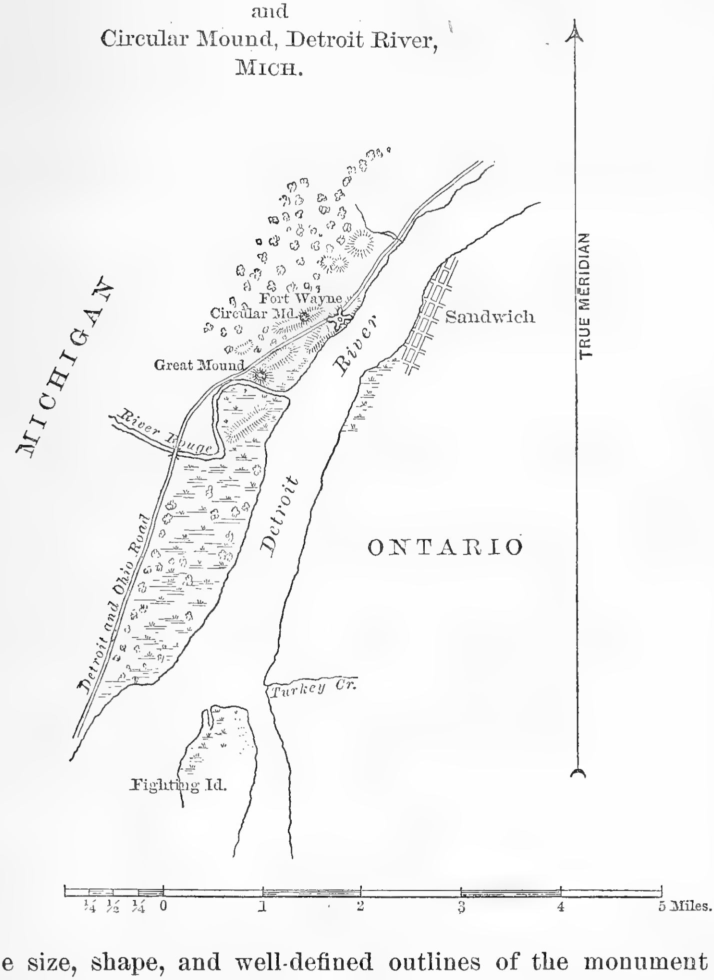
Some of those relics may, indeed, be said to be unique—unlike anything of the kind in any other part of this country or even in the Old World. I refer, for instance, to those which exhibit the flattening of the *tibia*, known as platycnemism.

That these people are identical with the race whose monuments of various descriptions are found occurring in such remarkable abundance to the westward and to the southward, through Ohio, Kentucky, and Tennessee, even to the Gulf of Mexico, admits now of no question; a race whose craniological development and evidently advanced civilization apparently separate it from the North American Indian and ally it to the ancient Brazilian type.

One of the most interesting works of this region, and which, till a few years ago, formed a member of a numerous series of mounds in the immediate vicinity, is the tumulus which I have named "The Great Mound of the river Rouge." This, in many respects, remarkable work is situated on the eastern bank of Rouge River, a tributary of the Detroit, and near the point of junction of the former with the latter river, or about four and one-half miles from the city-hall in Detroit. (See Fig. 1.)

Fig. 1

Great Mound, River Rouge, and Circular Mound, Detroit River, MICH.



The size, shape, and well-defined outlines of the monument could hardly fail to attract the attention of even the superficial observer, and impress him as to its being the work of man. With a height of 20 feet, it must originally have measured about 300 feet in length by 200

feet in width; but large quantities of sand have been removed from it from time to time, greatly reducing its proportions, and scattering or destroying a large number of interesting relics.

The series of smaller mounds, extending from the great mound to the eastward, has long since been entirely removed; so has the greater number of other similar mounds which once stood immediately below the southern city limits. Those which remain are fast disappearing before the march of civilization, the sand, of which they are principally composed, being in demand for building and other purposes.

Indian tradition says that these mounds were built in ancient times, by a people of whom they (the Indians) know nothing, and for whom they have no name; that the mounds were occupied by the Tuetle Indians, and subsequently by the Wyandotts, but were constructed long before their time. These facts were ascertained by me in the year 1869, when I was further informed that the Tuetle Indians had been absorbed by the Six Nations, and that if any survived it is among them they must be looked for.

In this connection it may be proper to state, that I have lately been informed of the results of some inquiries made at my request, through the instrumentality of the Smithsonian Institution, in regard to the name Tuetle. The conclusion arrived at is that the word Tuetle is probably a corruption of Tutelo, a tribe, "admitted as a younger member of the confederacy of the Six Nations about the middle of the last century," and that the Tuteloes "are believed to have migrated from Virginia northward, to lands assigned them on the Susquehanna by the Six Nations; but very little is known of their early history and migrations." An interesting paper on the Tuteloes, by Rev. J. Anderson, was read before the American Philological Association in July, 1871. Reporting Mr. H. Hale's discoveries, this assigns the Tuteloes to the Dakotan and not the Iroquois stock, and gives an account of Mr. Hale's "visit to Nikungha, the last survivor of the tribe of the Tuteloes," and who has since died at the age of one hundred and six years.*

The establishment of the identity of the Tuetles with the Tuteloes, and their residence on these mounds and along the Detroit River, is not without value, in view of Mr. Hale's opinion, (opposed to the conclusions of others regarding the Dakotan migration,) that "in former times the whole of what is now the central portion of the United States, from the Mississippi nearly to the Atlantic, was occupied by Dakotan tribes, who have been cut up and gradually exterminated by the intrusive and more energetic Algonkins and Iroquois."

The relics exhumed from the great mound (which has not even yet been thoroughly explored) consist of stone implements, such as axes, scrapers, chisels, arrow-heads, and knives; fragments of pottery of a great variety of pattern, including the favorite cord-pattern; and the

* Proceedings of American Philological Association, July, 1871, pp. 15, 16.

bones of man, generally much decayed, and exhibiting other indications of antiquity. From the fragments of burned bones and charcoal found it would appear that in the earlier interments cremation was practiced.

The *tibiæ* present, in an extreme degree, the peculiar flattening or compression pertaining to platycnemic men. In the Fourth Annual Report of the Peabody Museum mention is made of this; some of the relics which I collected from this mound having been given to the museum by the Hon. Robert C. Winthrop, to whom I had presented them. The curator, Professor Wyman, says: "Of the *tibiæ* of forty individuals, from the mounds in Kentucky, one-third presented this flattening to the extent that the transverse did not exceed 0.60 of the fore-and-aft diameter. The most extreme case was from the mound on the River Rouge, in Michigan, in which the transverse diameter was only 0.48. In the most marked case mentioned by Broca, viz, in the old man from Cro-Magnon, France, it was, as deduced from his figures, 0.60." Professor Wyman draws attention to certain resemblances in this bone to the same bone in the ape, adding: "In some of the *tibiæ* the amount of flattening surpasses that of the gorilla and chimpanzee, in each of which we found the short 0.67 of the long diameter, while in the *tibia* from Michigan it was only 0.48."*

Subsequent to this (in 1870) I discovered in adjacent mounds several instances in which this compression of the *tibia* was exhibited to even a greater extreme. Two remarkable cases of this peculiarity were afforded by *tibiæ* taken by me from the "Circular Mound" on the Detroit River. In one of those unique specimens the transverse diameter of the shaft is 0.42, and in the other 0.40, of the *antero-posterior* diameter; exceeding, I believe, any platycnemism which has been observed before or since. In communicating these facts to the American Naturalist, not long afterward, I claimed that the last-mentioned case "may be considered as the flattest *tibia* on record."† Both of the bones are strongly marked with the saber-like curvature, as are also many others of the *tibiæ* from the vicinity. The majority of the *tibiæ* present the flattening, which is an exception to the facts as noted in other sections of the United States, where it is supposed to pertain to "only about one-third of all the individuals observed."

About three-quarters of a mile to the north and eastward of the Great Rouge Mound, and only a few hundred feet to the westward of Fort Wayne, being over a third of a mile from the shore of the Detroit River, occurs the monument which I have named for distinction and from its originally symmetrical shape "The Great Circular Mound." This also appears to have been one of a numerous series, many of which have been removed for various purposes, but the present occupation of the land prevents a satisfactory examination of its character.

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* Fourth Annual Report of the Trustees of the Peabody Museum of American Archæology and Ethnology. Boston, 1871.

† American Naturalist, October, 1871, vol. v, p. 663.

A few years ago a great part of the mound was removed, and some important results were obtained, the relics being of unusual interest. Eleven skeletons were exhumed, with a large number of burial vases; stone implements in great variety and of superior workmanship, consisting chiefly of axes, spears, arrow-heads, chisels, drillers, and sinkers; pipes; ornaments of shell and stone; also, a peculiar implement of unknown use formed from an antler; and two articles manufactured from copper, one the remains of a necklace, consisting of a number of beads; the other a needle several inches in length.

One of the skulls is noticed by Professor Wyman as remarkable for its diminutive size, though adult, its capacity being only 56 cubic inches, or less than 67 per cent. of that of the average Indian cranium, which is given as 84 cubic inches by Morton and Meigs, the minimum observed by them being 69 cubic inches. In speaking of this skull, Professor Wyman says: "In ordinary skulls the ridges of the temporal muscles on the two sides of the head are separated by a space of from 3 to 4 inches, seldom less than 2, while in the Detroit-mound skull this space measures only three-quarters of an inch; and in this respect it presents the same conditions as the skull of a chimpanzee." *

It is interesting to remark here that "the flattest *tibiæ* on record," already referred to, were taken by me from this mound. I regret to have to add that in the rude method pursued in opening this mound many choice relics were destroyed; a large number also were carried away, scattered, and lost.

In the following table I give the dimensions of a few of the *tibiæ*, of which I was able to obtain measurements, from the great mound on the Rouge River and the circular mound on the Detroit River. All these bones have more or less saber-like curvature:

TABLE I.—*Dimensions, &c., of tibiæ from the Rouge and Detroit Rivers, Michigan.*

Number.	Length, in inches and decimals.	Transverse diameter, proximal end, in inches and decimals.	Least circumference, in inches and decimals.	Antero-posterior diameter and transverse diameter of shaft, in inches.	Perimetral index, in decimals of an inch.	Latitudinal index, in decimals of an inch.
1	....	2.9	3.5	167 by 97	....	0.580
2	....	2.7	....	145 by 70	....	0.482
3	....	....	....	156 by 78	....	0.560
4	....	....	2.7	117 by 68	....	0.581
5	14.7	2.8	2.65	148 by 67	0.180	0.452
6	14.9	2.7	2.8	142 by 69	0.185	0.485
7	....	....	....	168 by 80	....	0.476
8	14.6	....	2.7	152 by 64	0.184	0.421
9	15.0	....	2.9	154 by 62	0.193	0.402
Mean	14.8	2.73	2.87	150 by 72	0.185	0.486

* Sixth Annual Report of the Trustees of the Peabody Museum of American Archæology and Ethnology. 1873. American Journal of Science and Arts, third series, vol vii, p. 1, January, 1874.

In this table the latitudinal index expresses the amount of the compression of the shaft, while the perimetral index represents the thickness.

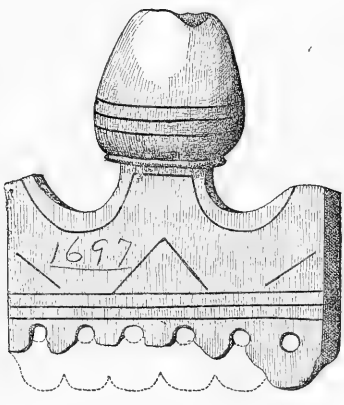
In this connection I wish to call attention to the fact that the perforation of the *humerus* is a characteristic which I have observed to pertain to the platycnemic specimens from the river Rouge mound. This is of great interest, as the peculiarity referred to is most frequently met with in the negro race, has also been observed in the Indian, and, though not always present, is quite general in the apes, while it is seldom seen in the white races.

The ridge on which Fort Wayne is built, once nearly a mile in length, on the bank of the Detroit River, and which occupies a commanding position, was, I am satisfied, previously occupied by the ancient people we are discussing. Their bones and implements have been dug out at that part of the ridge immediately above the fort. The leg-bones from this point also exhibited in a remarkable degree the flattening.

It is to be regretted that various circumstances prevented my obtaining in many instances the dimensions of the bones; otherwise I should be able to present an array of facts still more valuable.

Though the stone and other implements from the upper lakes cannot in general boast of the high degree of ornamentation observable in those relics from the southern portion of the United States, yet there are not wanting specimens evincing considerable cultivation in this direction. The difficulties of manipulation involved in the material used prevented the indulgence of much art. The pottery, therefore, seems to have been chosen especially for a display of such taste as those primitive workmen possessed in this field. The objects of this material from the lake-mounds present a remarkable variety of devices.

Fig. 2

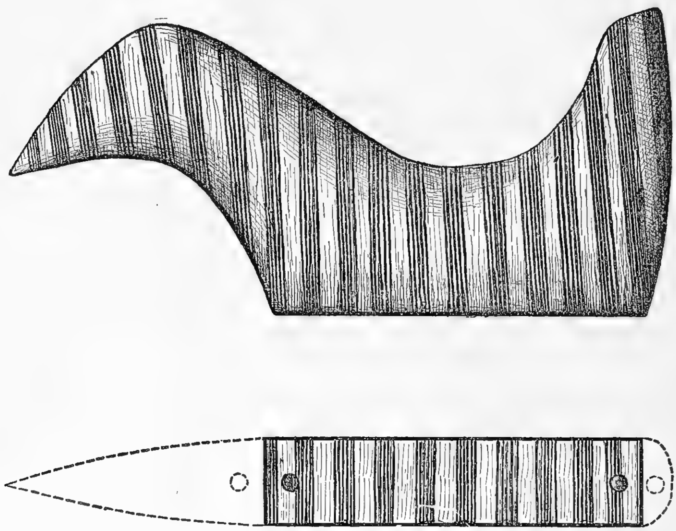


Stone Pipe from Grosse Point, Lake St. Clair, Michigan. Half size.

Figure 2 is an illustration of a stone pipe from Grosse Point, Lake Saint Clair, Michigan, which, as an object of this kind, is worthy of some admi-

ration. Though wanting in symmetry in its details, in its general appearance it is almost elegant, and even graceful. It is formed of greenstone, and is beautifully polished; the workmanship, as a whole, displaying much skill. This singular relic is in perfect preservation, with the exception of that part of the base, the restoration of which is attempted to be shown by the dotted lines. Of the bowl, which in shape resembles a half-closed tulip, a small portion is also wanting. The date, 1697, inscribed on one side of the base, is of interest. The antiquity of the pipe is in my opinion much greater than this would imply. Such relics are highly valued by the Indians, and handed down from generation to generation. The date of the settlement of Detroit is 1701; but the Jesuits and other white men had already penetrated to this region many years before. It is possible that some white person of note may have been presented with this pipe by its Indian possessor as a mark of respect, and that the former cut the date on this already-antique object. The four numerals, though distinct, are yet rudely cut, and are in marked contrast with the rest of the carving, being evidently the work of another hand.

Fig. 3



Section at base, showing oblique borings. &c.

Stone ornament from Grosse Point, Lake St. Clair, Michigan.
Full size.

A stone ornament from the same place is shown in Fig. 3. This is formed from a beautiful piece of variegated slate, of a grayish green, interstratified with veins of a darker shade, and is neatly made and finely polished. Similar ornaments have been found throughout the

United States; and as there has been considerable discussion as to their use, I will here state that I have learned, through an aged Indian, that in olden time these ornaments were worn on the heads of Indian women, but only after marriage. I have thought that these peculiar objects, which are always made of some choice material, resemble the figure of a brooding bird; a familiar sight to the "children of the forest;" that thus they are emblematic of maternity, and as such were designed and worn.

Fig. 4

Mounds at the Head of St. Clair River, and on Black River, Michigan.

In the year 1872 I made the discovery of one of the most remarkable and extensive series of *tumuli* which are known to exist in this part of the lake region. I refer to the mounds situated at the head of the

Saint Clair River, and which extend from a point south of Fort Gratiot for about one and one-half miles northward, along the west shore of the river and of Lake Huron. [Fig. 4.] A collection of a large number of relics was made by me from the location, and were forwarded, accompanied by a report on the subject, to the Peabody Museum. My paper, embodying the principal facts, subsequently formed a part of the annual report of the trustees,* and was afterward copied into several of the leading periodicals of the country, including the American Journal of Science.† The general publicity thus given the discoveries precludes the necessity of more than a passing notice here.

Those numerous mounds are, with few exceptions, of similar character, and were largely used for burial purposes. One of them presented some features distinctive of the "refuse-heaps" of our Atlantic coast and of the North of Europe, a wide area at one end being covered with "a solid crust of black ashes, from eighteen inches to two feet thick, containing the bones of various animals used for food, broken pottery, and stone implements."

The relics from the mounds, in addition to those usually found, consisted of an extraordinarily large number of broken stone-hammers of the rudest kind; a plate of mica five by four inches; and two necklaces, one made of small bones, stained a beautiful green color, resembling enamel, the other composed of the teeth of the moose, alternating with well-wrought beads of copper; and the bones of birds, stained green, as in the first instance. In the mound containing the last-mentioned ornaments several interments had been made, and the decayed stump of a scarlet oak, (*Quercus coccinea* Wang,) two feet in diameter, surmounted the summit, the roots spreading above the contents in all directions.

The human bones were all very tender from decay, and in most instances crumbled to pieces. All the *tibiæ* noticed by me exhibited the characteristic platycnemic compression. In dwelling on this circumstance, in connection with my previous discoveries in the same direction, I may remark that "I cannot but believe, from what I have seen, that future investigation will extend the area in which this type of bone is predominant to the entire region of the great lakes, if not of the great West; or, in other words, that at least the northern 'mound-builders' will be found to have possessed this trait in the degree and to the extent denoted;" which prediction recent discoveries in Wisconsin and Iowa would seem in a fair way to fulfill.

In the following table I present an exhibit of a few of the *tibiæ;* though I am convinced they do not show the extreme cases of compression occurring here, as most of the flattest bones fell to pieces before they could be measured. But such as it is, even, it is valuable,

* Sixth Annual Report of the Trustees of the Peabody Museum of Archæology and Ethnology. Boston, 1873.

† American Journal of Science and Arts, 3d series, vol. vii, pp. 1-9. January, 1874.

as a proof of the prevalence of this strange peculiarity. The mounds here and those on the Rouge River are over 60 miles apart.

TABLE II.—*Dimensions, &c., of tibiæ from the head of the Saint Clair River, Michigan.*

Number.	Length.	Transverse diameter, proximal end.	Least circumference.	Antero-posterior diameter and transverse diameter of shaft.	Perimetral index.	Latitudinal index.
1	14.5	2.7	2.9	155 by 83	0.200	0.535
2	15.0	2.7	2.9	155 by 82	0.200	0.529
3	.....	.....	.....	152 by 86	.....	0.566
4	.....	.....	2.5	140 by 77	.....	0.550
5	.....	.....	2.6	135 by 75	.....	0.562
Mean	14.75	2.7	2.75	147 by 80	0.200	0.548

These *tibiæ* were all taken from mound No. 3 of the report; which see for additional information of interest.

On the west bank of the Black River, a tributary of the Saint Clair River, is a burial-mound, which exhibited some unusual features. [Fig. 4.] A road having been cut through the easterly slope of this mound, the excavation consequent on grading, &c., revealed a large number of human bones, pottery, stone implements, and other relics. Stone-lance or spear-heads of great length were taken out, two of them being over a foot long, and one sixteen inches in length. But the most interesting feature of this repository of relics was a grave, the interior of which was described to me as being lined with pottery similar to that of which the vases, pots, &c., are formed. This was so peculiar a circumstance, no other instance of the kind having come to my knowledge, that at first I considered the statement rather doubtful. But not long after I availed myself of an opportunity of visiting the locality and making an examination.

Though the construction of the road through the mound had destroyed most of the original features, and scattered a multitude of valuable remains, further excavation revealed a considerable quantity of fragments of the pottery above referred to as having been said to have lined the grave. This certainly appeared to confirm the statement. I found this pottery to be of rather a coarser description than usual, and marked abundantly with the cord pattern, found to be of such frequent employment; but in this instance made with a large cord or small rope. The side so ornamented was invariably concave, while the other side was convex and unsmoothed; different from any other specimens I have seen elsewhere. So rough and unfinished was the unornamented side, that it had every appearance of having been pressed upon the ground while yet plastic, and sand, and even small pebbles, adhering to it sustained this impression. After having viewed the evidence, I had no longer any great difficulty in receiving the statements previously made.

My chief informant was perfectly uneducated in such matters, and

even attributed the peculiar formation lining the sides of the grave to the coagulation and final hardening of blood, accounting for its presence in such large quantity by presuming a battle to have been fought in the vicinity.

The few fragments of human bones which on this occasion were exhumed with the pottery were in the last stages of decay.

A large mound, which stands near the northwest shore of Chambers Island, in Green Bay, Wisconsin, I have thought worthy of mention here from having been the burial-place of platycnemic men, and as belonging to the lake region, though lying outside of the State of Michigan. It has been explored by a friend of mine of much experience in such operations, and I have had opportunity to examine the contents.

The accompanying sketch [Fig. 5] sufficiently shows the location, surroundings, &c., of this mound, which unquestionably is of great age. Among a large number of relics of the description generally found in the burial-mounds, there were exhumed here human remains, mostly in the latter stages of decay; a few rude stone implements; an urn (provided with a lid) of the old pottery, of uncommon design and curious indented pattern, formed largely of curved lines in a sort of scroll-work; and a broad, pointed copper-knife, well wrought, and resembling those found in the works of the "ancient miners" of Lake Superior. Fragments of prepared hide, like rough leather, adhered to the knife; probably the remnants of a rude sheath. One of the skulls, in fair condition, presented decided indications of artificial flattening, while the *tibiæ* al. exhibited the peculiar compression already referred to, though not to the extent found to pertain to the *tibiæ* of the mounds along the Detroit, Rouge, and Saint Clair Rivers. The bones of one of the earliest of the interments gave unequivocal evidence that cremation had been practiced here. Large pieces of charcoal, well preserved, remained in the vicinity of the burnt bones.

The annexed table gives the dimensions of some of the *tibiæ* preserved from this mound, from measurements which I have carefully made. The platycnemism of those bones is of importance, as still widening the area over which the peculiarity prevailed.

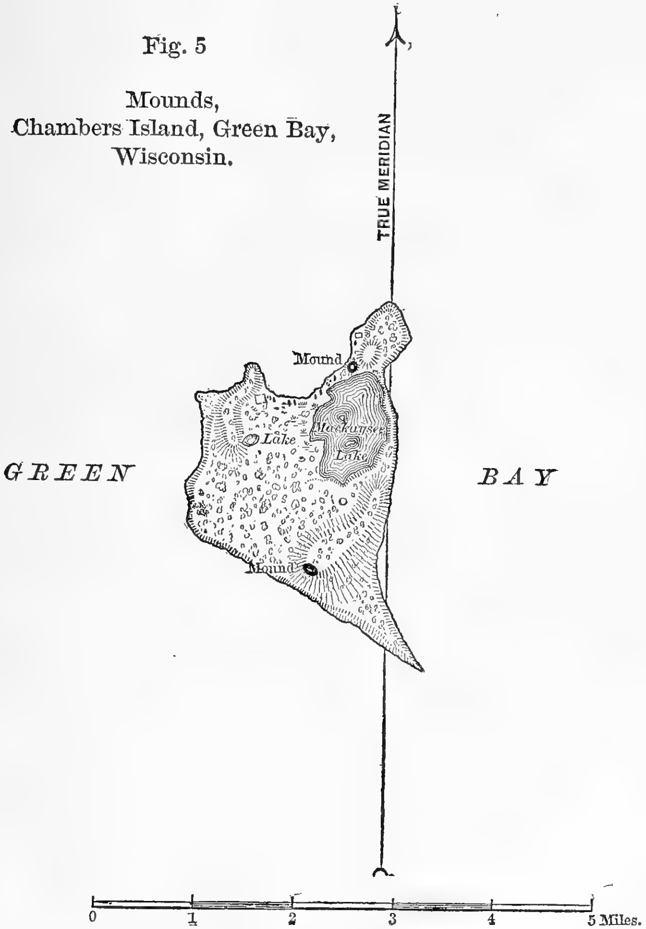
TABLE III.—*Dimensions, &c., of tibiæ from Chambers Island, in Green Bay, Wisconsin.*

Number.	Length.	Transverse diameter, proximal end.	Least circumference.	Antero-posterior diameter and transverse diameter of shaft.	Perimetral index.	Latitudinal index.
1	15. 54	3. 05	3. 00	153 by 95	0. 190	0. 620
2	15. 48	3. 00	3. 07	155 by 86	0. 198	0. 554
3	14. 15	3. 15	3. 00	152 by 88	0. 212	0. 579
4	13. 80	3. 10	3. 04	155 by 93	0. 220	0. 600
Mean....	14. 74	3. 07	3. 02	153 by 90	0. 205	0. 588

The mound shown on the southwest side of Chambers Island [Fig. 5] was noticed and partially examined by me several years ago. It was then much undermined by the waters of Green Bay; the contents, principally human bones, being somewhat exposed by the giving way of the high bank. I have lately learned that within the last few years this mound has totally disappeared, owing doubtless to the cause just referred to. It belonged unquestionably to the larger class of burial-mounds, and was probably of like age and origin as the mound at the northwest end of the island.

Fig. 5

Mounds,
Chambers Island, Green Bay,
Wisconsin.



In this connection it is of importance to refer to the late discovery by Mr. Dawkins of platycnemic men at *Perthi-Chwaren*, in Denbighshire, Wales, and to Prof. G. Busk's valuable notes on those ancient remains.* Professor Busk and Dr. Falconer were the first, I believe, to call attention, in 1863, to this particular conformation of the leg-bone in the

* Journal of the Ethnological Society of London, January, 1871.

human remains from the cave on Wind-mill Hill, Gibraltar,* giving to it the name of "platycnemic." M. Broca, in May, 1864, independently, observed the same condition in *tibiæ* from Chamant and Maintenon, in France.†

Similar bones were noticed at Montmartre, by M. Bertrand. Professor Wyman found the same peculiarity in *tibiæ* from the Florida mounds, in this country, and it was through the last-named gentleman that my attention was called to the subject, some bones which I had procured from the mound on Rouge River, in Michigan, first establishing the fact that this platycnemism was a characteristic of the northern tribes of aboriginal man on this continent. Discoveries of flattened *tibiæ* have also been made in Kentucky and Tennessee; while the mound I have mentioned as occurring on Chambers Island adds Wisconsin to the list; and I have lately been informed of like discoveries having recently been made at Davenport, Iowa.

The following table gives the proportions of the *tibiæ* from Denbighshire, as taken by Professor Busk, with slight corrections, which I have made in revising the computations:

TABLE IV.—*Dimensions, &c., of tibiæ from Perthi-Chwaren, Wales.*

Number.	Length.	Transverse diameter, proximal end.	Least circumference.	Antero-posterior diameter and transverse diameter of shaft.	Perimetral index.	Latitudinal index.
1	14.9	2.8	3.2	140 by 80	0.214	0.57[illegible]
2	13.7	2.7	2.9	120 by 75	0.211	0.625
3	13.2	3.0	3.0	135 by 80	0.227	0.592
4	12.9	2.5	2.5	125 by 70	0.193	0.541
5	12.9	2.5	2.75	100 by 70	0.213	0.700
6	....	....	....	135 by 90	....	0.666
7	....	....	....	140 by 90	....	0.642
8	....	....	....	130 by 70	....	0.538
9	....	....	....	135 by 85	....	0.629
Mean	13.5	2.7	2.87	129 by 79	0.212	0.612

As before explained, the latitudinal index designates in each instance the amount of flattening of the bone; the perimetral index representing, with some approach to exactness, the thickness or bulk of the shaft; and on a comparison of the preceding table, giving the proportions of those ancient *tibiæ* from Wales, with the tables in which I have given the dimensions of the *tibiæ* from the mounds on the Detroit and Rouge Rivers, the greater platycnemism of the latter bones will at once be apparent.

A further comparison with the normal form of the ordinary English *tibiæ* is afforded by the subjoined table, prepared by Professor Busk,

* Transactions of the International Congress of Prehistoric Archæology for 1868. p. 161.

† Mémoires sur les ossemens des Eyzies: Paris, 1868. Reliquiæ Aquitanicæ, p. 97.

which gives the dimensions of "thirteen leg-bones taken indiscriminately from a drawer in the College of Surgeons, London." I have made a few corrections, however, in re-computing from Professor Busk's elements

TABLE V.—*Dimensions, &c., of ordinary English tibiæ.*

Number.	Length.	Transverse diameter, proximal end.	Least circumference.	Antero-posterior diameter and transverse diameter of shaft.	Perimetral index.	Latitudinal index.
1	16.7	3.15	3.4	130 by 100	0.203	0.769
2	16.4	3.2	3.5	150 by 115	0.212	0.766
3	15.8	2.95	3.0	120 by 90	0.189	0.750
4	15.5	2.95	2.9	140 by 90	0.187	0.642
5	15.3	2.9	2.8	130 by 90	0.183	0.692
6	15.2	3.0	3.2	140 by 90	0.210	0.642
7	15.0	2.8	2.8	140 by 90	0.187	0.642
8	15.0	2.6	2.8	120 by 85	0.187	0.708
9	15.0	2.6	2.8	120 by 90	0.187	0.750
10	15.5	3.0	2.9	120 by 95	0.187	0.791
11	13.5	2.8	2.9	120 by 90	0.214	0.750
12	13.4	2.75	2.7	120 by 85	0.201	0.708
13	12.8	2.5	2.4	100 by 85	0.187	0.850
Mean	15.0	2.86	2.9	127 by 92	0.195	0.727

While the *tibiæ* from the Detroit and Rouge Rivers show a degree of platycnemism somewhat in excess of that of the *tibiæ* from the head of the Saint Clair River, the latter have more of this peculiarity than the Chambers Island specimens, which, in turn, have this compression to an extent slightly greater than the bones from other (more southerly) parts of the United States, as given by Wyman; the last mentioned being of about the flatness of the Welsh bones from Perthi-Chwaren, which, as we have seen, are much flatter than the ordinary English *tibiæ*.

The data for determining the perimetral indices are in some cases hardly sufficient for establishing any positive statement; but, at least in the American and Welsh *tibiæ*, the slenderness of the bone appears to be related in some degree to the flattening; *i. e.*, the more platycnemic *tibiæ* (taking the means) are the more slender. In individual instances, however, this does not hold good. The ordinary English *tibiæ*, it will be noticed, are not so thick as the Perthi-Chwaren specimens, but in this respect come between the *tibiæ* from the Detroit and Rouge Rivers and those from the Saint Clair. Excepting the *tibiæ* from Chambers Island, a remarkable uniformity, it will be observed, exists in the means of the "transverse diameters of the proximal end;" and the same may be said of the "least circumferences." In length the ordinary English *tibiæ* (modern) are in excess; the Michigan and Wisconsin specimens come next; while the ancient Welsh *tibiæ* are much the shortest.

For convenience of reference, I append a table exhibiting a comparison of the means of the different tables already given.

TABLE VI.—*Means of the dimensions, &c., of tibiæ.*

Locality.	Length.	Transverse diameter, proximal end.	Least circumference.	Antero-posterior diameter and transverse diameter of shaft.	Perimetral index.	Latitudinal index.
Detroit and Rouge Rivers, Michigan..	14.80	2.73	2.87	150 by 72	0.185	0.486
Head of Saint Clair River, Michigan..	14.75	2.70	2.9	147 by 80	0.200	0.543
Chambers Island, Wisconsin..........	14.74	3.07	3.02	153 by 90	0.205	0.588
Perthi-Chwaren, Wales...............	13.5	2.7	2.87	129 by 79	0.212	0.612
Ordinary English, College of Surgeons, London.	15.1	2.86	2.9	127 by 92	0.195	0.727

I refrain from indulging in any extended deductions which will naturally be suggested by the comparison of the different tables here given. Professor Busk and M. Broca have pointed out so fully the various relations of this conformation of the leg-bone as to leave little room for general comment. I would simply add, that the platycnemism which I have observed in Michigan all appears to belong to what is termed "anterior;" that is, this abnormal expansion of the bone is in front of the interosseous ridge. In this respect the Michigan specimens resemble the *tibiæ* from Denbighshire rather than those from Gibraltar and from Cro-Magnon; in the two latter instances the expansion being posterior. "The occasional and not infrequent platycnemism observed in the shin-bones of negroes," Mr. Busk states, "is what may be termed 'anterior.'" He is not prepared to discuss what this difference may indicate, though he considers that, "in all probability, it is connected with a difference in the cause of the deformation, (if it be deformation.)"

As to the ethnological value of this platycnemism, he considers "we are as yet very much in the dark," doubting the probability of its being a race-character, "though it may undoubtedly be considered a character betokening remote antiquity." After referring to certain distinctions between the human and the simian foot, he concludes with asking: "Would it not, then, be admissible to inquire how far, at any rate, posterior platycnemism may be connected with the greater freedom of motion and general adaptability of the toes enjoyed by those peoples whose feet have not been subjected to the confinement of shoes or other coverings, and who at the same time have been compelled to lead an active existence in a rude and rugged or mountainous and wooded country, where the exigencies of the chase would demand the utmost agility in climbing and otherwise?"

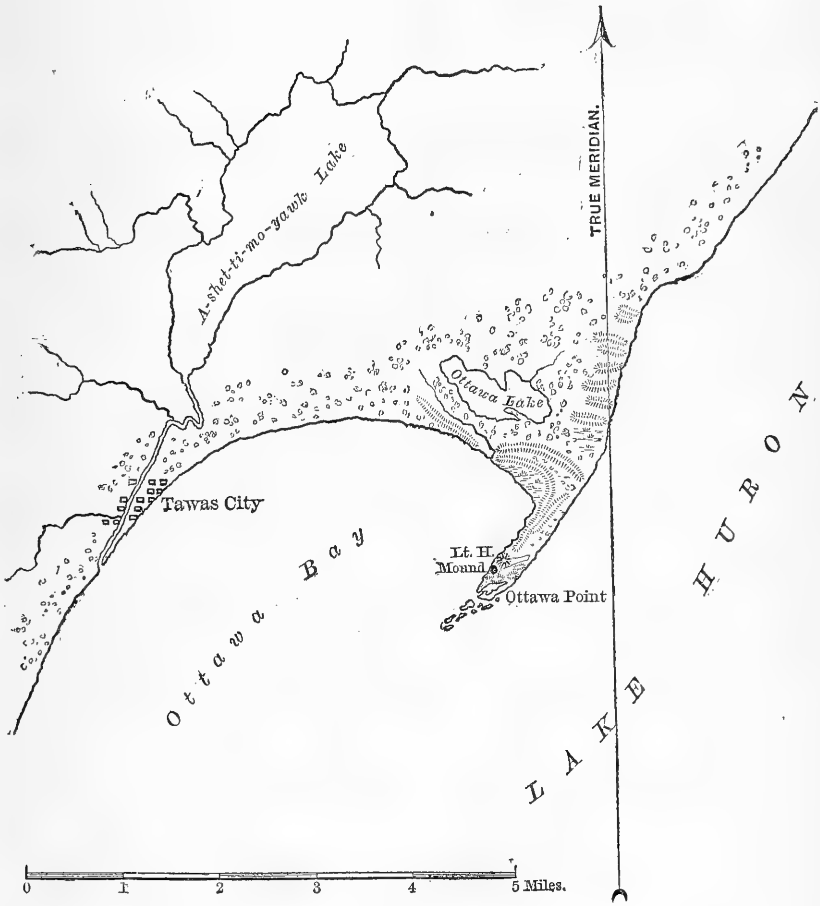
Further observations of abundant material from different parts of the country, and perhaps of the world, are wanted to afford the requisite testimony as to the ethnological significance of this peculiarity.

In the year 1856, I found a small burial-mound on the west shore of Ottawa Point, Michigan, (Lake Huron.) [Fig. 6.] It occupied the bank, close to the beach, and the washing of the lake in storms had under-

mined it, causing it to cave away on one side, and partially disclosing the contents.

Fig. 6

Mound at Ottawa Point, Michigan.

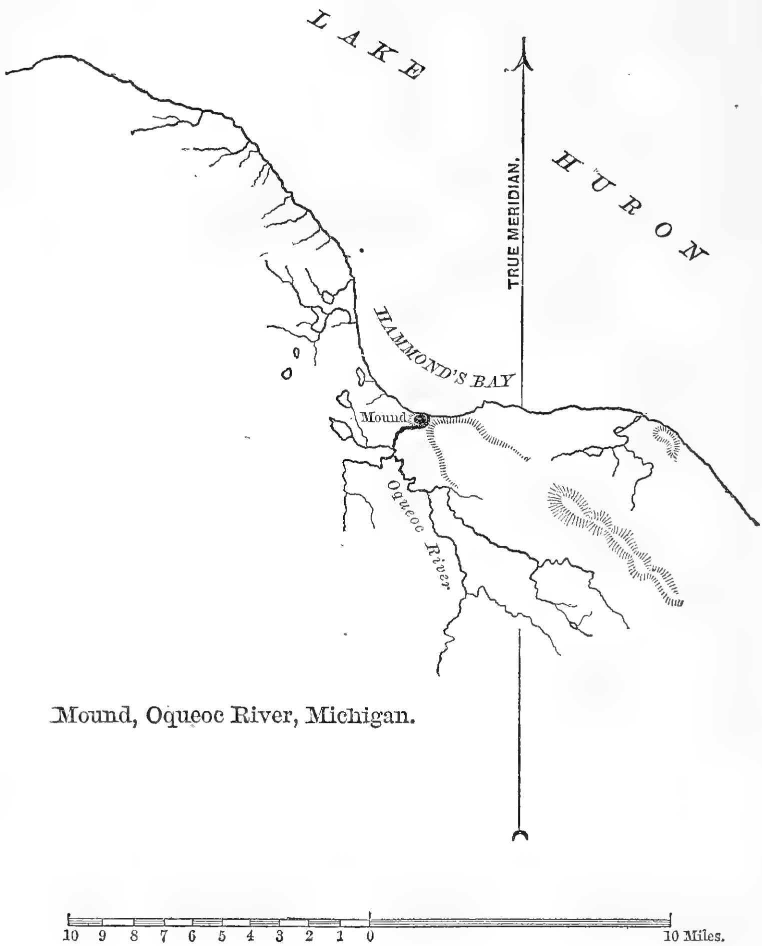


On examination, nothing was found establishing for the work any great age. The utensils, trinkets, &c., were all of a period subsequent to the advent of the white man. There was, in fact, no point of resemblance between this place of sepulture and those of the "mound-builders." The bones exhumed apparently belonged to one body—probably that of a woman.

On visiting the same point some sixteen years afterward, (June, 1872,) all trace of the mound had disappeared, doubtless through the encroachments of the lake.

A mound similar to this was seen by me at Oqueoc River, Lake Huron, [Fig. 7;] and another at Point La Barbe, in the Straits of Mackinac. [Fig. 8.] No opportunity was afforded in either case for a thorough

Fig. 7



Mound, Oqueoc River, Michigan.

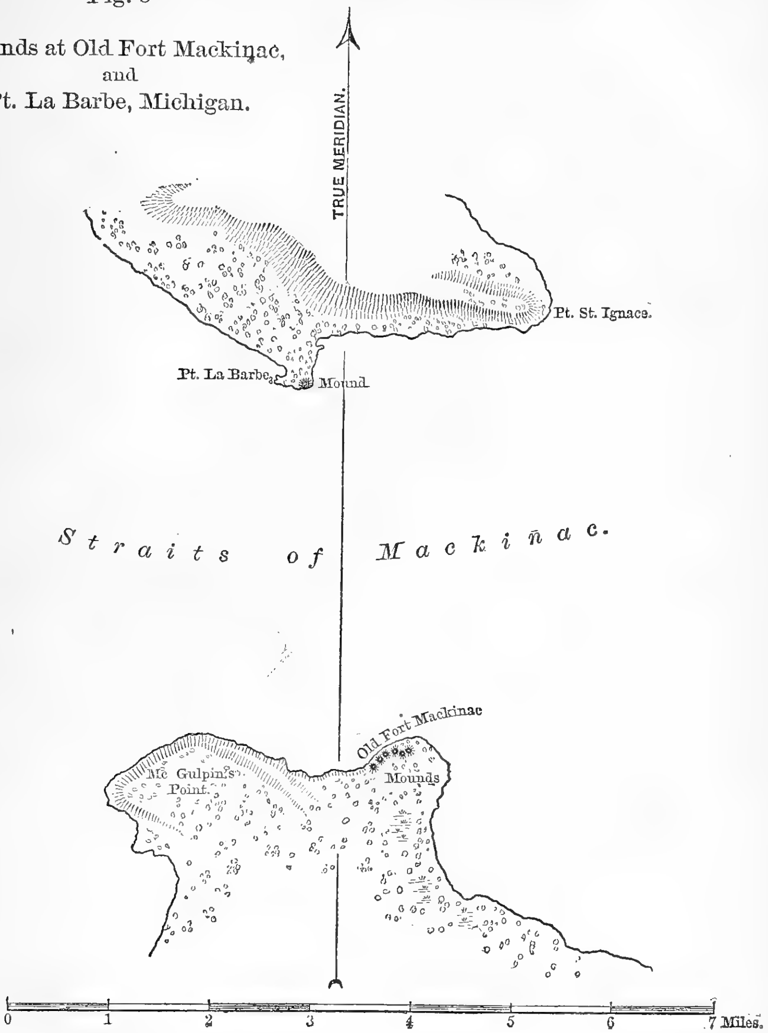
examination of the contents. In fact, such mounds are frequent all along the lake shore, and seem to be invariably of more recent origin than the first-described works. They are generally quite small; and it is observable that they are frequently situated in such places as present some features of natural beauty.

At old Fort Mackinac, opposite Point La Barbe, on the south shore of the Straits of Mackinac, occur several interesting mounds, [Fig. 8,] which have never to my knowledge been thoroughly examined. Long before the European selected this point for a fort, or even the present

Indian race had frequented those shores, man had here taken up his habitation; evidence of which was seen in the usual mounds.

Fig. 8

Mounds at Old Fort Mackinac,
and
Pt. La Barbe, Michigan.



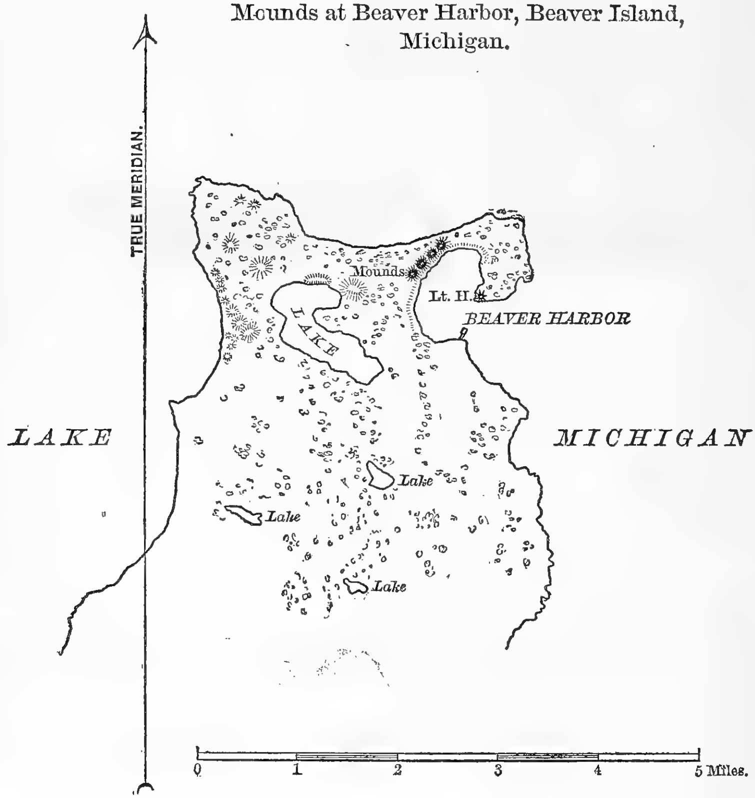
When the writer, in 1851, visited the site, attractive from its historical associations, nothing remained on the bleak, sandy point to denote the original works of any of the races who had dwelt there save a few mis-shapen mounds and the remnants of the pickets which once had formed the sally-port, near which was the stump of the flag-staff, projecting about two feet above ground. These last were fast being undermined by the waters of the straits, which washed within a few feet of them; and, as in stormy weather the waves must have swept clear over them, in all probability they have long since disappeared. The

great massacre and capture of the fort occurred on June, 1763; and till within the last few years the place has not been occupied since ten years after that event.

A remarkable series of mounds occurs at Beaver Harbor, on Beaver Island, in Lake Michigan. [Fig. 9.] They are at present chiefly occupied by the town of Saint James, which was built by the Mormons, under their leader, James Strang, ("King Strang,") about the year 1852–'53. The mounds, which overlook the harbor, are extensive; and though, so far as I am aware, they have never been systematically investigated, they doubtless present a rich mine for research.

Fig. 9

Mounds at Beaver Harbor, Beaver Island, Michigan.



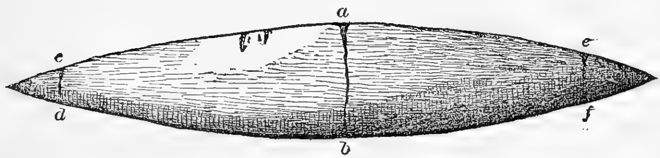
A very limited and hurried examination which I made of them in 1871 sufficiently satisfied me as to their ancient origin. They appear to be of the same character as the mounds on the Detroit River and at the foot of Lake Huron. They were probably largely used for purposes of sepulture, and until a comparatively recent period even the present race of Indians has continued to inter the dead, though not perhaps in the same repositories, at least in their immediate vicinity. From the success attending

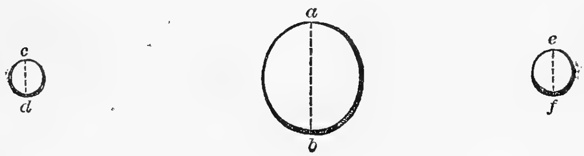
my brief labors, it would appear that the more valued relics of the "mound-builders" have been here deposited in unusual abundance. Highly-wrought stone implements, many of them being of uncommonly skillful workmanship, are frequently encountered. These consist of axes, chisels, fleshing-tools, sinkers, spear-points, arrow-heads, &c., formed of a great variety of stone, such as diorite, sienite, greenstone, shale, and chert, many of them being finely polished.

One of the handsomest stone-axes I have seen was taken out at this place. It is made from sienite, a favorite material for this implement, and the handicraft displayed in its construction is of high order. Another ax, of diorite, is exquisitely polished.

Fig. 10

Stone implement,—Beaver Harbor Mound, Michigan.
Full size.





Sections at the three grooves, *c-d*, *a-b*, and *e-f*.

The implement [Fig. 10] found here, and presumed to be a sinker, I have thought it worth while forwarding a sketch of. The grooves shown at its middle and at each extremity, though shallow, are distinctly marked, and the entire implement is elegantly finished; apparently too much so by far for the purpose for which it is supposed to have been designed. It is made from a grayish shale, and is slightly polished.

Another stone implement from those mounds is the large circular upper stone of the utensil conjectured to have been employed for grinding the grain used as food. This stone, which is also of sienite, is finely worked, being much smoother on one side than on the other. It is possible it may have been employed for another purpose than that suggested.

Immense amounts of the fragments of pottery of the usual description and patterns (the well-known cord-pattern being frequent) are found here

In quality it compares favorably with that from the Detroit and Saint Clair River mounds.

I think it of importance to state here that on exhibiting some of the pottery to several of the more intelligent of the Indians at present resident on one of the neighboring islands, they professed their ignorance as to its manufacture, but attributed it to an ancient people, who preceded them in the occupation of this country. Among the Indians so questioned was the chief, a man of large stature, striking personal appearance, and much dignity of manner, and who is noted for his knowledge, intelligence, and judgment.

I also specially remarked the indifference with which they beheld the examination of the mounds (which they appeared to have no knowledge of) and the abstraction of the relics. When it is considered how sensitive and jealous the Indian is as to any interference, even of the most trifling kind, with the burial-place of his people, this would afford another argument toward establishing proof of the distinctness of the mound-building race from the North American Indian. I have known Indians evince the greatest anxiety and anger on the displacement of the little slip of wood on which the totem of the deceased was painted. When the remnants of the Pottawatomies, once resident on the Detroit River, migrated westward, they consigned with the strictest injunctions the care of the burial-place of their people to friends among the white inhabitants, making certain concessions or grants in return for the most solemn promises of the observance of this protection. But this trait of character is so well known to pertain to the Indian as to require no special illustration here.

The "ancient mining" on Lake Superior was first brought to notice in the winter of 1847–'48. The first discoveries were made on Keweenaw Point, and extended to Ontonagon, which afterward proved to be the center of the great copper region of Michigan. As is well known, various accounts of those works have been given to the public. Subsequently some "ancient diggings" were found on Isle Royale, Michigan, near the north shore of Lake Superior; but the isolated position of the island operated to prevent any extensive knowledge of the field.

In the year 1872 some of the most remarkable of the ancient works yet encountered were brought to light by a party of mining explorers on Isle Royale. The amount and character of the work here revealed was something so extraordinary as to almost exceed belief.

The facts, as ascertained during a brief visit I made to Isle Royale in May, 1873, were embodied by me in a short paper, entitled "Ancient Works at Isle Royale, Michigan," which was some time afterward published in Appleton's Journal, attracting considerable attention.* A subsequent visit to the island, made by me in August of the same year contributed additional discoveries of interest.

The works referred to are generally pits of from a few feet to thirty

* Appleton's Journal, August 9, 1873, vol. x, p. 173.

feet in diameter; some being quite shallow, while many reach a depth of from twenty to sixty feet. They are scattered throughout the island, wherever the amygdaloid copper-bearing rock is found, and are invariably on the richest veins; great intelligence being displayed in locating and tracing the veins and in following them up when interrupted, &c. To quote from my paper, "This has elicited the astonishment of all who have witnessed it—no mistakes apparently having been made in this respect. The excavations are connected under ground, drains being cut in the rock to carry off the water. Stopes one hundred feet in length are found. A drain sixty feet long presented some interesting features; having been cut through the surface-drift into the rock, it had evidently been covered for its entire length by timbers felled and laid across. When opened, the timbers had mostly decayed, and the center portions had sunk into the cavity, filling it for nearly its entire length with the rotted wood." The amount of mining on three sections of land, at a point on the north side of the island, is estimated to exceed that of one of our oldest mines on the south shore of Lake Superior, "a mine which has been constantly worked with a large force for over twenty years." When we compare the tedious methods of the primitive miners, and all the disadvantages under which they must have labored, with our modern improvements in mining appliances and all our resources, this may well appear almost incredible.

At another point the excavations extend, in nearly a continuous line, for more than two miles, the pits being often "so close together as barely to permit their convenient working. Even the rocky islets off the coast have not escaped observation, and where bearing veins of copper are generally worked." But it is probable that, including all the discoveries, not one-tenth of the excavations have been disclosed.

"The method of mining pursued by this people was, evidently, on turning back the overlying drift, to heat the rock by the application of fire; then, when by dashing on water the rock was sufficiently disintegrated, to break and pulverize it with their great hammers." The rude stone-hammers or mauls, weighing from ten to thirty pounds, are found in surprising quantities. With this exception no tools of stone have been observed. A large part of a wooden bowl, originally about three feet in diameter, which had probably been used for bailing water, was taken from one of the pits. Fragments of charcoal abound. The tools formed of copper consist principally of chisels and knives. Arrow-heads of the same material are frequently collected.

Having seen the remark that the copper tools of the "ancient miners" are of rough and not polished exterior, inferences being drawn therefrom as to their rude construction, I wish to say that, having examined a large number of the tools, I believe this roughness to have been mostly caused by corrosion. In many cases this is quite palpable, the original surface being apparent in places, and evidently confirming the fact that at least the external faces of the tool were originally approximately smooth, if not polished.

Various arguments have been advanced by Mr. Foster to prove that the "mound-builders" understood the art of fusing copper, and that at least some of their copper tools were made by being cast or molded.* From the method pursued by this people in mining, in which the agency of fire bore so prominent a part, it would seem improbable they could have long remained ignorant of the fusibility of the metal; yet in most cases the evidence appears conclusive that the rudely-fashioned tool was simply wrought by being beaten into the desired form, often in the roughest manner. It is possible the two classes of tools here referred to may mark two distinct eras in the history of this manufacture, and that the molded tool designates an advance from the primitive method of hammering the metal into shape. Some of the copper beads taken from the "mounds" display a wonderful degree of neatness in the manipulation of the metal, the junction of the bead being in many cases almost imperceptible; yet the agency of fire was here evidently not employed.

As to the time occupied by the operations, and the interval which has elapsed since the suspension of work at the mines, approximate estimates are made from data which are given by me in the paper already quoted from, and to which I must refer the reader for this and other information. That the latter period may extend from seven hundred to eight hundred years does not appear to me to be far from the truth.

The present growth of forest covers, unbroken, the pits, the *débris* excavated from and surrounding them, and the detritus at the bottom, containing stone, copper, and other implements; all the timber being of the same character as that on the adjacent land. Several generations of trees have probably grown there since the desertion of the works. On the *débris* at the mouth of a pit an old stump of an oak, (probably *Quercus coccinea*, Wang.,) which had grown and decayed there, was examined, which, from the calculation made by counting the annual rings, &c., must have reached the age of five hundred and eighty-four years before it ceased to grow. A copper knife and other implements were found beneath this stump. Pines of the present forest (*Pinus strobus*, L.) have frequently been cut in the pits, which trees the number of the cortical layers make three hundred and eighty years old.

The absence of the bones of man is a remarkable feature. Accepting the identity of the "mound-builders" with the "ancient miners," it may be supposed that, through some superstitious belief, they had the habit of removing their dead to burial-mounds farther south.

It is evident that such extensive operations as are here described required a system and organization of no mean order for those days. Besides the animal food afforded by the land and the water of the surrounding region, it is likely that, as the Mound-builders were essentially

* Phreistoric Races of the United States of America: Chicago, 1873, p. 259.

an agricultural people, and largely dependent on cereals for sustenance, grain-food was transported to the island in sufficient supply from a more southern latitude. The so-called "Garden-beds," covering so wide an area of the Saint Joseph River and Grand River Valleys, Michigan, as well as similar grounds of other places, demonstrate the agricultural habits of the ancient people of this region. The remains of those cultivated fields also afford a clue as to the source of the chief part of the supplies required for the mining adventures in the northern country.

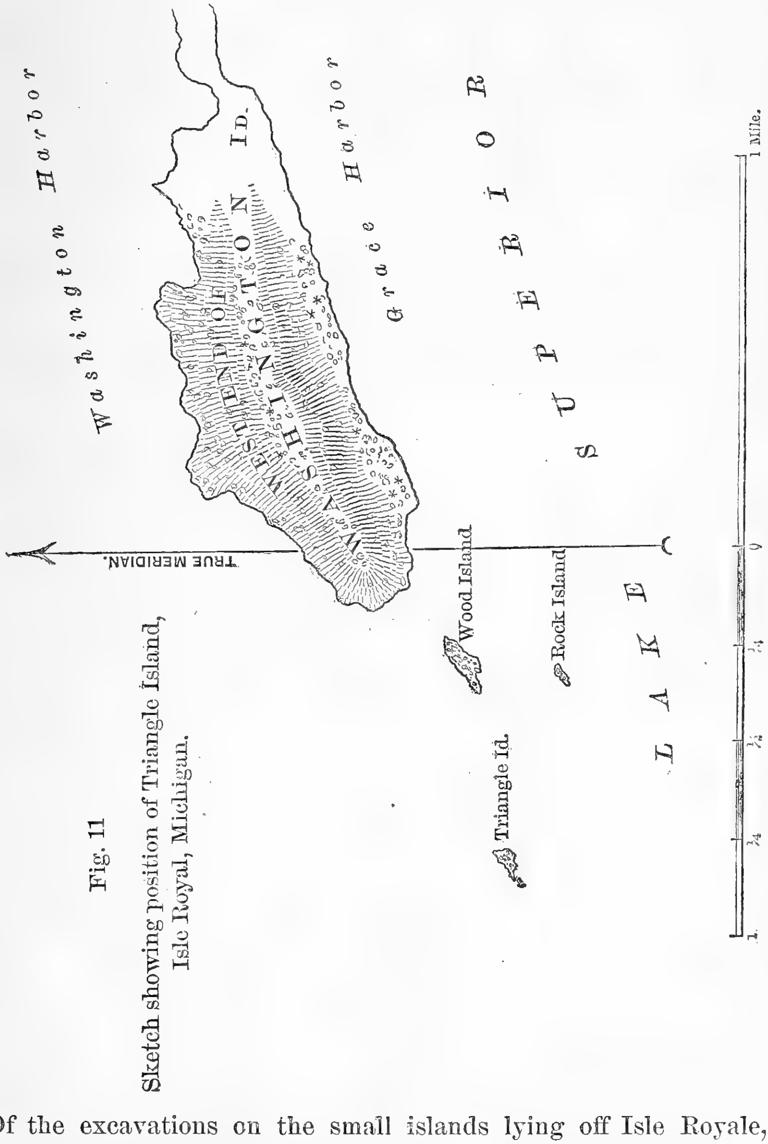


Fig. 11

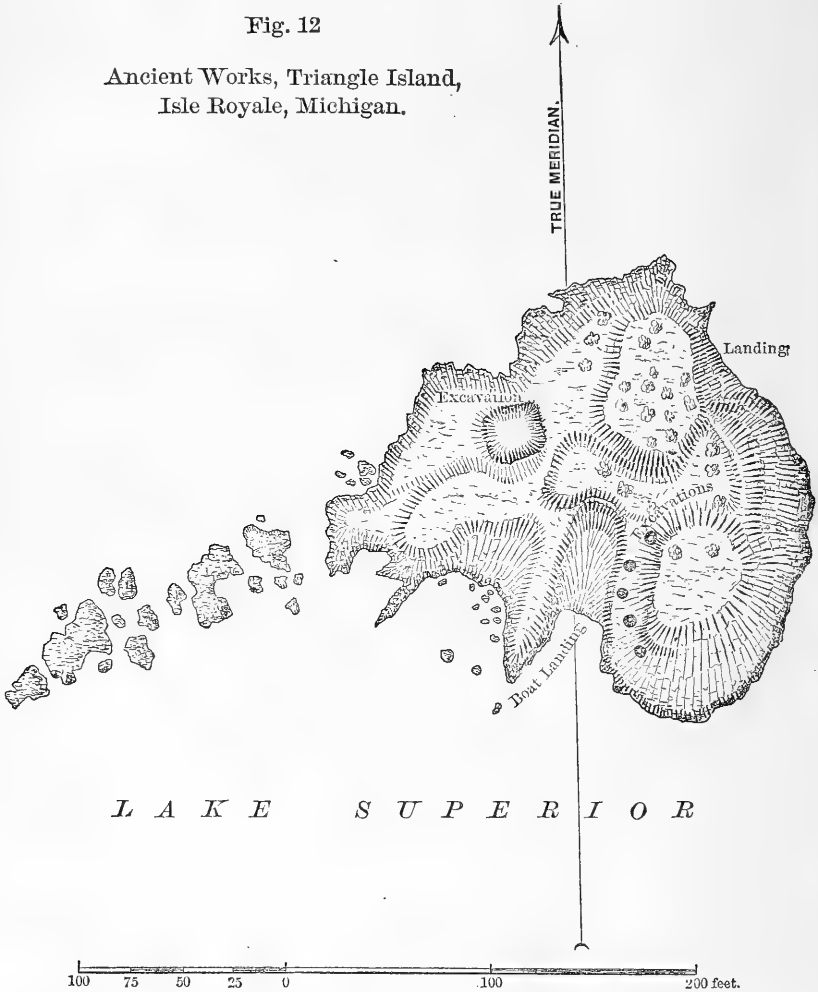
Sketch showing position of Triangle Island, Isle Royal, Michigan.

Of the excavations on the small islands lying off Isle Royale, an interesting example was discovered by me on the rocky islet which, for the purpose of distinguishing it, I have named, from its general outline,

Triangle Island, it being hitherto unnamed on any of the maps. This island lies about three-quarters of a mile southwest of Washington Island, the largest of the islands off the southwest end of Isle Royale, and forming a part of the boundaries dividing Grace from Washington Harbor. [See Fig. 11.]

Fig. 12

Ancient Works, Triangle Island, Isle Royale, Michigan.



Triangle Island is a sandstone rock, with very little soil on any part of it. The rock, which is full of inequalities, fissures, and clefts, is exposed over the greater part of the island, though the northeast end, the highest part, (18 feet above the lake-level,) is partially covered with bushes of *Cornus stolonifera* and a few stunted trees of very small size (little better than bushes) of mountain ash and poplar. The sides of the island rise abruptly, and there is no landing for even small boats, except for a short space on the northeast side and also in a cleft-like indentation on the south side, [Fig. 12.] The natural conditions of

this last-mentioned landing appear to have been improved by artificial means. It is 20 feet wide by about 60 feet in length, and has a gradual slope to the lake, the rock being generally smooth throughout. On each side are perpendicular walls of rock. Small boats could easily be hauled out here, particularly with the aid of timbers laid for the purpose. Near it, and all along it, wherever there are indications of copper-veins, are the circular pits of the "ancient miners." Though of small size, (from 2 to 5 feet in diameter and about as many feet deep,) they are remarkably distinct. At this place the rock is mostly as level as the floor of a room, and the well-like pits are immediately perceived to be the work of human agency.

Though the pits were carefully searched, no relics were met with, other than the angular fragments of the rock, broken off by the usual methods pursued by those rude miners. The fragments occasionally contained copper.

One of the small pits, a little over two feet in diameter and nearly two feet deep, had a large, irregular slab of rock covering its mouth. It required two men to remove this. We found the pit more than half-full of the angular fragments above alluded to, ranging from less than a cubic inch up to more than two cubic inches in size. From the indications we hoped to find this the repository of some valuable relics; but, though the hole was emptied of its contents, nothing other than already mentioned was encountered. Had any tools or other utensils been deposited here as a place of safety, they had long since disappeared; probably decaying through the lapse of ages. From appearances, and the isolated character of the island, I am inclined to think that my hands were the first to touch these objects since the departure of the primitive workmen.

At two places, at each end of the circular pits, the copper-veins in the wall-like cliff had been attacked and partly excavated. The rock was discolored as if from the action of fire, and at the base of the more central point the sandstone was considerably hollowed. All those works exhibit the same roughish surface, totally unlike that produced by the action of water.

Immediately at the end of the southern landing, already described, is a marked depression, occupying nearly the center of the island, and presenting some indications of artificial origin. But about 35 feet northwestward of the head of the landing occurs a more remarkable excavation. This is of rectangular form, 25 feet by 20 feet, and with an average depth of nearly four feet. It is filled with water, as are the pits. The sketches already referred to [Figs. 11 and 12] supply such further information as I was able to obtain.

It may not be uninteresting to state, in this connection, that I found the rare fern, *Botrychium lunaria*, Swartz., flourishing, and rather abundant on the exposed rock of this island. It grew in tufts of *Potentilla tridentata*, Ait., grass, and other dwarfed plants.

I shall conclude with the following quotation from my paper on Isle Royale, to which I have already had occasion to refer:

"The discoveries on Isle Royale throw a new light on the character of the 'mound-builders;' giving us a totally distinct conception of them, and dignifying them with something of the prowess and spirit of adventure which we associate with the higher races. The copper, the result of their mining, to be available, must, in all probabilty, have been conveyed in vessels, great or small, across a stormy and treacherous sea, whose dangers are formidable to us now, being dreaded by even our largest craft, and often proving their destruction. Leaving their homes, those men dared to face the unknown, to brave the hardships and perils of the deep and of the wilderness, actuated by an ambition which we to-day would not be ashamed to acknowledge."

The question will not fail to suggest itself, Were these vast operations accomplished through slave-labor? That a conquered people were kept at this isolated place by their victors, and in this thraldom obliged to work the copper-mines, is an opinion, however, which "cannot be received without further confirmation."

THE LEIPSIC "MUSEUM OF ETHNOLOGY."

Condensed from "Extra-Beilage zu No. 104 der wissenschaftlichen Beilage der Leipziger Zeitung," (translated for the Smithsonian Institution by Mr. Arthur Schott,) and from "Erster Bericht des Museums für Völkerkunde in Leipzig, 1873."

By Otis T. Mason.

The science which has man for its object stands in a relation to auxiliary sciences somewhat similar to that of a statue to its underlying base; it can be lifted to its position only after they are ready to receive it, and then, though towering above them, is supported by them. Slowly and with painful care must these foundation-stones have been wrought out and set in place. Flaws in the material, faults in plan, and mistakes in execution have more than once compelled the builders of the past to tear down the whole structure and to commence anew. It is for us to inquire whether we are even now prepared to make a systematic arrangement of the facts respecting the human race, and to put in order those objects which illustrate the somatical and psychical constitution of man as well as his manners and customs.

We are quite sure that neither an ethnological scheme nor a museum of universal ethnology could have been possible at any previous age of the world, although we have abundant evidence to prove that thoughtful men, bringing to the investigation the peculiar spirit of their times, have always considered the study of man himself to be the worthiest of all pursuits.

Nor can we now hope to make an exhaustive arrangement of the

phenomena and accessaries of human life. We can only attempt such a classification as will render accessible and useful that which is at hand, for the purpose of showing the present condition of our knowledge as well as our deficiencies; and also in what directions further research should be made. The advantage of such an exhibition to the education of youth and to the improvement of scientific observation and taste among the masses of our intelligent countrymen is incalculable.

Having spoken of the relation which the study of man bears to auxiliary sciences, we come to inquire more particularly into these studies, and also briefly whether they are sufficiently advanced to be helpful in working out the truth respecting humanity in general.

So complex is the nature of man that a number of sciences are confined to it alone, viz, anatomy and physiology, with the kindred sciences of pathology and medicine, or the sciences of the human body; psychology, subdivided into branches specially devoted to conscience, reason, and volition, and linguistics, or the sciences of the human soul; sociology, ethnology, history *par excellence*, and the philosophy of history, which may be called the sciences of man's social nature; to which may be added anthropology, or the science of the human species in relation to other organic beings. Each of these has had a deeply interesting and important record. Each has passed through exceedingly diversified experiences in order to be a competent witness of facts necessary to the general result. While accumulating material for their own completion, they have, designedly and undesignedly, reached conclusions of universal significance.

Among the nations of antiquity, the Greeks were the first to pay any attention to anatomy. Is it not astonishing that the inspection of the carcases and entrails of thousands on thousands of human and animal sacrifices never suggested to the enlightened priests of Egypt, Syria, and the Tigro-Euphrates nations, the simplest truths on this subject? Even the Greeks themselves studied the human body more for the purposes of medical practice than for the classification of the facts about it. Their analyses of the races of men were based on the hair, the color of the skin, or some other mere superficial character. Aristotle knew scarcely anything about the human skeleton. Hippocrates had a better understanding of osteology, although his knowledge of anatomy was meager enough. The Alexandrian school, basing their knowledge on experience, deserve credit for pursuing a method which yielded little to them indeed, but rich results to those who followed up their investigations. The names of Erasistratus of Ceos, Herophilus of Chalcedon, and Celsus shine out among these early investigators. The line of the celebrated physicians of antiquity closes with Galen, (born at Pergamos, A. D. 130,) whose decisions upon many important points of human structure were for fifteen centuries the dicta of the doctors. We grope in vain amid the darkness of the middle ages for evidences of advance in the knowledge of general anatomy, or anatomy of the species. Notwithstanding Roger

Bacon, Silvius, and a few others, the teachings of Galen had remained so little affected that when Andreas Vesal proved in the sixteenth century, by his own observations, the errors of Galen, the public were willing to believe that human nature might have changed, but not to believe Galen in error. Mondino da Luzzi, professor of anatomy at Bologna, first publicly dissected two human bodies in the presence of medical students. Gabriel Fallopio, of Modena, enjoyed the rare privilege of being allowed to dissect seven corpses annually, among them the bodies of convicts, whom he had killed previously with opium. Bartolomeo Eustachi, after whom the "Eustachian tube" is named, the victim of a poverty which kept from publication his "Tabulæ anatomicæ," and "which," says Lauth, "retarded anatomical studies two centuries," completes the medieval triumvirate. With the discoveries of Harvey, human anatomy began that rapid growth which has brought it, in our day, well nigh to perfection, and numbers among its investigators many of the most eminent names in science. The same is true of physiology and biology. Faint glimmerings dart up along the ages, of truths, of principles, of analogies, of accurate definition, of guesses bordering on inspiration, which in our day have blazed out in brilliant deductions, verified by experiment.

From the earliest times, psychology has received more attention than somatology. The human soul has been scrutinized from various points of view. Scarcely a nation existed in ancient, medieval, or modern times that has not had its schools of thought, so that it is possible to begin to bring together, out of the writings of philosophers of the various schools, in the order of their historical development, those metaphysical discoveries which have added to what we might call general or comparative psychology, or those facts of the human soul upon which ethnological relations are founded, together with the laws of their infancy, growth, activity, and decay.

Gathering together the testimony of ancient and modern travelers, historians, and conquerors, of missionaries, explorers, and traders of modern times, respecting the different ideas entertained about God, a future life, and the soul's prospects therein, about all the relations which go to make up the present life, together with the languages, rites, and customs, in which those thoughts find expression, we shall have man revealed to us in every stage of culture, from savagery to the highest civilization. The earth opens her mouth to testify of the men who passed away before the dawn of written history, the knowledge of whose far-distant origin and of their progress through different stages of social development is illuminated by every object of human economy in our collections.

The first result of this extension of knowledge is classification on special bases: wherefore we should naturally imply the results of the labors of Camper, founded on the facial angle; of Blumenbach, on the *norma verticalis;* of Morton, on the cubical contents of the skull; of

Retzius, on cephalo-gnathism; of some, on the skull-bases; of others, on skin, hair, pelves, &c; of Latham, on language; of Max Müller, on religion. Though not always pursued and published in a proper spirit, these labors are necessary in every possible line of investigations. Let us have more of them. Failure to find the truth, after an honest effort, is helpful and commendable. Greater patience, with more improved instruments on other paths, will give results which will become the axioms of higher generalizations.

In the second place, a number of sciences considered as auxiliary to a knowledge of the human race have reference to its environment. Among these are chemistry, physics, meteorology, geology, and one knows not where to stop in the enumeration. We find man bound up with his material surroundings by a threefold cord: he resembles it; he depends upon it; he subdues it. A knowledge of the facts concerning these relations is so necessary to an understanding of himself that great progress in a variety of sciences, and an impartial and comprehensive view of them, become necessary to a just appreciation of the difficulties of ethnological research.

Nearly every law of human embryology, anatomy, and physiology has been discovered or confirmed through the study of animals and plants. Man resembles all creatures in his amenability to the laws of climate and physical forces. So great is the similarity of his body to that of the animals of related species that it is hard to find anatomical characteristics worthy to be co-ordinated with the overwhelming differences between his mental powers and theirs. The same food nourishes; the same law of decay returns them back to the dust. The floods sweep over them and they are gone. Their records are read side by side in the drift-gravels of the river-beds.

The dependencies of man are twofold—those which he has in common with other creatures, and those by which climate, food, the fertility of the soil, the constancy and suitableness of material supplies, confine him, determine his character and destiny; by which the poverty of some places starves him, the luxuriance of others enervates him, the adaptability of others to his body and mind supplies just those helps, stimulants, and rewards which conduce to his symmetrical development. When we consider how many upheavals and deposits have helped to prepare a single acre of ground for his appearance and growth upon it, or how many ages of the operations of all the forces of nature, and how many species of natural objects minister to him in savage and in civilized life, we come to regard him as the most helpless and needy of all beings, and we must admit the necessity of an acquaintance with all these in order to have a correct appreciation of him who is their adopted child.

We come now to regard man as nature's conqueror; for, like the science which reveals him, he that was erst the infant and most defenseless of all creatures, comes in his later years to be the spoiler of the universe. By the sweat of his brow he earns his bread and clothing

and shelter; by the sweat of what is beneath the brow, I mean the brain, he earns the food that nourishes the soul. He takes the models of his material implements and comforts and the methods of his handiwork from nature. He clothes his thoughts in words of natural imagery. He utilizes the forces of nature. He makes the winds and the seas to serve him. He finds his way by the refraction of the rays of light which the stars shed down back to the stars, and learns the secrets of their going.

If, then, we are to treat man properly, we cannot be satisfied with a discussion of one part of his nature or of one phase of his life. Ethnology, and anthropology, its handmaid, undertake to explain the origin, antiquity, unity of race, primitive condition of the human species; its relation to lower beings, as well as to its material environment; the cause and historical development of its implements, clothing, weapons, shelter, amusements, public life, social phenomena; of its geographical starting-point and distribution; of its language, religion, present condition, and future prospects. Too much honor cannot be paid to the philosophers of Greece, to the schools which they founded, and to their successors in medieval and modern times, for their application of the inductive method to metaphysical studies. Too much honor cannot be paid to the long line of anatomists from Hippocrates to Owen and Huxley, who have found their way, little by little, through the labyrinths of his mysterious body. But most honor will be due to him who shall grasp the theme in its entirety, and give to all the facts their true import in the series. Meanwhile, it is for each of us, however humble, to bring his gift to one common altar, and for all to co-operate in paying due homage to a science which must eventually receive what is good and true in every method of investigation.

We come now to consider the best means of exhibiting the facts and objects of human culture. The same rule of proceeding from particulars to generals, from specialties to a comprehensive view, are in force here. There are many public and private museums in Europe and America devoted to single sides of culture. They cover nearly every part of the work of general ethnology, embracing the prehistoric records of drift, cave, lake-dwelling, kjökkenmöddings, shell-heaps, mounds, rude stone monuments, &c., and coming down through the civilizations witnessed by the Nile, the Tigro-Euphrates, the Ganges, the Yang-tse-Kiang Rivers, by the Mediterranean, the Black, and the Caspian Seas, we shall find evidences of their condition in special collections for their illustration.

Just as the generalization of all our knowledge concerning the earth constitutes the true study of the cosmos, as the aggregation of the sciences auxiliary to ethnology is the basis of our knowledge of culture, so, too, the existence of these vast and valuable special collections make it possible to begin to group together those objects which will illuminate our investigations about the tribes of men regarded as parts of one

common brotherhood. Considering geographical, isothermal, chronological, tribal, linguistic, and religious divisions as subordinate, we must adopt that order for which we are indebted to Wachsmuth and others in general, but to Dr. Gustav Klemm in particular, which considers humanity as one, and believing its progress to be as a whole ever onward and upward, seeks to illustrate by the arrangement of objects in a museum, reinforced by models, copies, photographs, drawings, charts, and an ethnological library, the growth of civilization in all those respects wherein it has manifested itself. To quote the words of Klemm.

"As natural science investigates, singly, the earth, the phenomena which occur in and around it, the air, the water, the mountains, the rocks, the plants, the animals, and mankind as parts of a grand whole, and then groups them together, so also should the historian study and seek to comprehend and exhibit the human race, in all its members, as a totality, in its origin, development, present condition, and future prospects, in all its tendencies and relations."

"Therefore, our point of view can be neither a political one, which exhibits man in relation to the state, nor a literary, an artistic, an antiquarian, nor an industrial one, but that from which to observe and study the gradual development of humanity out of a condition of childhood, or one closely approaching the brute creation, up to its separation into organized communities, embracing all their adjustments, together with their relations to culture, knowledge, skill, to domestic and public life in peace and war, to religion, science, and art developed among influences arising from climate, geographical position, and the providence of God. Mankind is an individual whose organism, like that of a human body, has its mysterious birth, its infancy, youth, and manhood, wherein it grows and waxes strong; and the possessor of intellectual affections, it is the spiritual germ and bud which are destined to become flower and fruit; ever growing old, it is to be ever renewed, until it fulfills the end for which God created it. It is the objective view of humanity upon the different stages of its development, rising one above the other, or its whole life, so far as we are in position to trace it backward and forward."

"The method which we ought to follow can scarcely be any other than to study the various peoples of the earth in different times and places; to consider carefully their condition; and then to classify them conjecturally according to their place in the series. To-day we find the different tribes of the world existing in diverse degrees of culture—the Indio da Matto and the Bosjesman, without shelter or personal possession; the Arctic tribes, covered with fur and grease; the Negro and the anthropophagous New-Zealander, contemporary with the skillful Chinese, the cultivated Japanese, the thoughtful German, just as ages ago the wandering Scyths, the Sarmatian savages, were with the Egyptians, the Greeks, and the Romans. If, therefore, we were to follow the guiding threads of geography or chronology in arranging our material, we should

scarcely produce a faithful picture. If we were to take as a basis the historical development of any one people, say the Greeks, the Romans, or the Germans, we should find ourselves perplexed by reason of two inevitable difficulties. In the first place, there is no authentic information about the earliest history of any one of these nations handed down to us by their neighbors whose observations and records are accessible to us. The origins of nations are as much overlooked by historians as the infancy of great men. We have to be content with vague traditions. In the second place, there never has been known a nation in which have appeared all these phases of development. We must, therefore, scrutinize all the successive stages of culture among different tribes of ancient and modern times, and arrange them in such order as to gain a view of the growth of the race. We will set aside the usual geographical, ethnographical, and synchronological arrangements, and divide the races of men into three fundamental classes—the savage, the barbarous, and the enlightened, (represented in time, roughly, by the stone, the bronze, and the iron age.)"

"I. *The condition of savagery.*—Mankind comes from the hand of the Creator a double being, that soon increases to the *family*. Oblivious of the past and of the future, he thinks only of his daily wants. Here we trace the origin of *society*, in the family; of *religion*, in *shamanism;* of *technics*, in the search for stones to serve as tools."

NOTE.—Doctor Klemm, considering nature as the foundation of culture, regarded with especial attention those objects from its three kingdoms which furnished man the means of subsistence and action without further preparation, and which became the models of his earliest manufactures. Among these are the frost-formed and water-worn and pierced pebbles, immense deposits of which are found in many places, and which assume almost every shape, afterward adopted for tools in the stone age. To these are to be added hooked sticks, curiously twisted and knobbed roots, spiral vines, tubes of reed, combinations of wood and stone, thorns, teeth, bones, claws, hedge-hog quills, shells, and many other objects, a fine collection of which graced his celebrated museum.—O. T. M.

"Permanent settlements, personal property in lands and herds, and organized governments have no existence."

"II. *The condition of barbarism.*—Herein families have increased to tribes which restrain and confine each other, and who submit themselves to the wills of superiors, who strengthen their power by alliance with the realms of the Invisible, and assume to be prophets, priests, and even the sons of the deities. They build for themselves holy places and cities, and guard them with especial care. The adornment of these shrines develops art, especially architecture, music, and dancing. The desire to preserve the record of the most important events gives rise to hieroglyphics, word and syllable writing. So far as it is possible under priestly rule, the nomadic and stationary modes of life are developed successively. The different grades of this series are represented by the

Otaheitan, the Malay, the Mexican, the Egyptian, the Chinese, and the Jew. It is the condition of limitation."

"Finally the *free nation* occupies the topmost grades of culture. The yoke of priestcraft is broken. Intellectual forces expand in all directions. Laws to regulate internal affairs, foreign treaties, eager desire for adventure, the spirit of research, of striving after the remote and the difficult—these are the phenomena here exhibited. The Persian, the Arab, the Roman, are examples of this, but above all the German race furnishes the most perfect examples of this condition of culture, having Christianity as its peculiar agency for the destruction of hierarchical rule."

In perfecting this scheme, Dr. Klemm expended many years of time and energy, gathering what has been considered the best collection of objects of human culture. On his death, this rich and unique material, which had cost him 25,000 Prussian thalers, besides containing donations to an equal amount, was offered for sale by his heirs, first to the royal government of Saxony, which favored its purchase for the University of Leipsic. The commissioners, Professors Wuttke and Overbeck, appointed by the university to examine the collection, reported, the former in the most flattering terms, in favor of procuring the treasure. But, for reasons not necessary to state, the university decided against receiving the gift. The heirs of Klemm, fearing that the collection would be scattered and its usefulness destroyed, offered to take 10,000 thalers for it, on the condition of its becoming the nucleus of a museum of universal ethnology at Leipsic. The offer was accepted and the accompanying circular was issued by the Board of Regents, in order to explain the constitution and design of the "Leipsic Museum of Ethnology."

It was in the year 1869 that the committee was organized in Leipsic for the purpose of founding a museum of the history of culture, which should be an honor not only to the city but to science. There existed already, elsewhere, magnificent and richly endowed collections of ethnological objects. These, however, call especial notice to natural history or geographical facts, and pay attention to culture-historical development only in a more or less secondary manner.

The chief impulse to this undertaking was given by the circumstance that the celebrated museum of the royal Saxon privy-counselor and chief librarian, Dr. Gustav Klemm, of Dresden, was offered by his heirs at public sale. The committee published an appeal, soliciting contributions for the purchase of this material and for the foundation of a general anthropological museum. They hoped not only to be able by this means to foster science, but also to develop a patriotic spirit in securing to the fatherland the Klemm collection, which would otherwise be scattered in foreign countries.

From the beginning, the labors of the committee had such success, that although the demands of the heirs of Klemm were not immediately

and in all points satisfied, yet the purchase would have been consummated in 1870. The whole business was brought to a happy close by a contribution from His Majesty King John of Saxony, as well as by extraordinarily rich presents, which, to the extent of many thousands of thalers, were secured from unknown friends of the enterprise through Prof. Dr. Bruhns and Privy-Counselor Dr. Hoffmann.

Shortly before the breaking-out of the memorable war in 1870, the objects were brought to Leipsic, where, through the kindness of Prof. Dr. Kolbe, they next found a provisional location in the building of his chemical laboratory.

Hereby the first part of the task, the possession of the Klemm collection, was completed. Now arose a scarcely less important and imperious demand, to procure a proper place for setting up and exhibiting the objects. Through the almost total want of suitable room, in spite of the most earnest and persevering efforts, more than a year was needed in order to meet the new exigency. Through the prompt co-operation of the council of the city of Leipsic, and especially of the deputation for the Saint John's Hospital, the spacious and well-lighted halls in the second story of the old hospital-building (46 Grimm street) were procured at a moderate rent. Of course, these very ill-adapted apartments had first to be transformed and suitably fitted up. This duty also, a not insignificant care, was lightened for the committee through the means of the before-mentioned members, who, anew by rich contributions, proved themselves to be worthy patrons, and, in a praiseworthy manner, added new proofs of their public spirit and benevolence. To them our warmest thanks are due. When enough had been done to meet the most pressing needs, it became necessary to provide for the permanence, the maintenance, the internal perfection, and the extension of the collection. In addition to this, it was necessary to elevate the hitherto fluctuating committee into a self-perpetuating and more powerful corporation.

In order to obtain a larger number of members, embracing all branches of society, and to acquire incorporated rights, the provisional directory thought best to call a meeting in order to define more clearly the constitution of the society. A printed invitation to all citizens of whatever class, brought together, on the 23d of March in the past year, in the great saloon of the highly-esteemed Board of Trade, a great number of friends of the undertaking. On motion of the chairman of the directory, Prof. Dr. Leuckart, Consul-General Gustav Spiess accepted the presidency. He opened the meeting with a few remarks upon the design of the published invitation. Doctor Obst next gave a short review of the previous labors of the committee, described the contents of the Klemm collection of historic culture, and dwelt upon the importance of a museum of ethnology which should unite systematically all objects illustrating the human race and the history of its development. Mr. Gustav Plaut, the banker, made a short report upon the condition of the treasury; and Mr. Rudolph Schmidt, the attorney, gave his opinion upon the

system of rules already drawn up. These were, upon the motion of Mr. Emmerich Anschütz, the attorney, approved as a whole, whereby the future government of the society was empowered to make any necessary minor changes. The name "Museum of Ethnology" was adopted. They next proceeded to the election of the Board of Overseers, which was carried by acclamation to the unanimous result given in the appended list. These all signified their willingness to accept. Finally, Doctor Delitsch made the agreeable statement that the society would receive a very valuable collection of Swiss lake-dwelling antiquities from a patroness, who already, at different times, had favored their enterprise with friendly cheer and rich gifts, and now offered a birth-day present on the event of its first coming out. After a vote of thanks for such an interesting and unexpected public spirit, accompanied by such an offering, the meeting adjourned.

The Board of Visitors subsequently met and elected the following officers: President, Prof. Dr. Bruhns; vice-president, Doctor Delitsch; secretary, Mr. Kaufmann Rosencrantz.

They then proceeded to the election of a Board of Regents, which resulted in the unanimous choice of Prof. Dr. Leuckart; Privy-Counselor Prof. Dr. Peschel; Doctor Obst; Consul-General Gustav Spiess; Gustav Plaut, the banker. These all declared their willingness to serve in the office to which they had been elected.

In a called meeting of the Board of Overseers, on the 3d of April, 1873, the revision of the laws which had been submitted in the constituent meeting was taken up. They were finally and unanimously adopted as they stand in the "Constitution and Instructions" which accompany this paper. The next task was the setting-up of the collection, in order to make it as accessible as possible and to increase its usefulness. Immediately they went to work arranging it in the rooms which they had obtained and put it in proper order. The not insignificant expenses were provided for in the most liberal manner by the Board of Overseers, so that the museum, in its outward appearance, is not unworthy of its valuable contents. The extraordinary extent of the work as well as the great scarcity of workmen everywhere, whereby the making of the necessary cases and show-tables was much impeded, have still more delayed the exhibition of the collection and disappointed the hopes and wishes of the Regents. Then came the order from the Board of Overseers, an extremely auspicious event, not to allow the Vienna Exposition to pass without making it useful to the museum, which rendered it necessary for Doctor Obst to intermit his work and to remain some time in Vienna. For the purpose of making necessary purchases, a stated sum of money was placed at the disposal of Doctor Obst by the council of administration. Affairs took such a favorable turn at the exposition that the agent was able to return loaded with foreign treasures without spending the means so liberally provided. Only a proportionally small part was used for necessary expenses.

Upon a more accurate knowledge of the circumstance that a museum

of ethnology had been founded in Leipsic, not only for the benefit of science, but for the greater progress of arts and industry, a great part of the commissioners of the exposition were found ready, at the solicitation of Doctor Obst, to assign to him whatever of their material was useful for the purposes of the museum. In the first rank we must name the royal Japanese Commissioners to the Exposition, from whom the museum, through his excellency, Mr. Sano Tsunotami, minister resident in Vienna of His Majesty the Emperor of Japan, received a rich collection of objects of all kinds, not only interesting but exceedingly valuable. For his lively interest in the museum we are most profoundly obliged to Minister Sano, after whom we not less acknowledge the service of Baron Alex. von Siebold, secretary of the royal Japanese legation at Vienna, and of Mr. Henry Jonkheer von Siebold, interpreter of the Austro-Hungarian commission in Japan. Both of them, as well by their means as by their influence and solicitation, have been of great service to our enterprise. Besides, the museum also received valuable gifts from the exposition through Mr. Vladimir, Count Dzieduszycki, Baron Overbeck, the Austro-Hungarian consul-general at Hong-Kong; from Alois Klammerth, royal porcelain-manufacturer in Znaim; from Villeroy and Boch, in Metlach; as well as from His Excellency Count Fradesso da Silveira, and from the Spanish and Italian commissioners to the exposition. All of these honored donors will hereby please to accept our warmest thanks.

Scarcely of less importance to the museum than these rich presents are the numerous and indissoluble sympathies which have been created in all lands, and the personal influences which have sprung up in favor of the enterprise, through which the museum cannot fail to have a prosperous future.

As an especial sign of the importance of the museum, and of the favor of which it may justly feel proud, it may be noticed that the general administration of the Royal Museum in Berlin has offered to the Museum of Ethnology duplicates of the ethnological objects in its collection. We believe that a gift so extensive and costly will not fail to result by its praiseworthy example very favorably for our cause.

Finally, we are in prospect of receiving consignments from the different parts of Europe, from East India, China, Japan, Australia, Africa, the South Sea, America, &c. The Smithsonian Institution at Washington, the Ethnographical Museum at Leyden, as well as the Society of Anthropology and Ethnology in Moscow, have promised whatever they can spare to the Museum of Ethnology. In like manner, our thanks are due to the honored mission of the brethren at Hernhut for furthering our scheme.

We cannot close without returning thanks to Professor Bastian in Berlin, and to Counselor Dr. von Scherzer, royal Austro-Hungarian general consul in Smyrna. With untiring interest from the very beginning they have tried to further the aims of the society in every practical way.

THE APPEAL.

Endowed with incorporated rights, an institution has been founded at Leipsic, which, under the title of "Museum of Ethnology," has for its aim the collection of all objects illustrating the nature and history of culture of the human race and the encouragement of the science of ethnology.

The most celebrated known collection of objects of human culture, the property of the late Doctor Klemm, chief librarian at Dresden, forms the starting-point of the enterprise, which, already increased by rich donations, will shortly be arranged in a suitable place.

In behalf of the institution, the undersigned appeal to all those who are interested in the nature and historical development of the human species with an earnest plea for the support and furthering of their scheme.

The scientific progress of ethnology and the diffusion of knowledge concerning our race are the objects which they have in view. In order to obtain them, they need the enthusiastic co-operation of all ethnological societies now existing; and upon them they call so confidently because it is proposed to accomplish a work which, inasmuch as it concerns the general welfare, so also only through the general patronage can it be called into life, and be brought to maturity.

There are already, in Berlin, Munich, Vienna, London, Paris, St. Petersburg, Copenhagen, and other cities, rich anthropological and ethnological museums; but dependent, as they are, upon the government which founded them, and upon the public patronage which they receive, they represent at best only—though perhaps magnificently—special branches and single directions development of the culture; whereas the Leipsic "Museum of Ethnology" shall have as its object to bring into one general view the nature and productions of the human race of all ages and countries. Surely it needs only the mention of such an undertaking to lead it to a successful result. Furthermore, it is fortunate that Leipsic is the city which developed this idea, and through not insignificant offerings, has given the first impulse to its execution. Lying in the heart of Germany, indeed, of civilized Europe, a rallying-ground for the whole world, it ought, as well from its geographical situation as from its expanding, ever-augmenting influences, from its position in the commerce of the world, from its profitable and extensive monetary affairs, from its manifold intellectual and material productions, from the importance and patronage of its still growing university, to be the fittest among many illustrious cities to organize an institution adapted to the purpose and to make it most abundantly successful.

We are not ignorant that the task before us is great and difficult; but we are firmly confident that we, in our endeavors to perform it, shall have aid and sympathy for every branch of our work.

We are already able to boast of many notable subscriptions and presents, which have made it possible for us to begin the collection, and to call into existence the "Museum of Ethnology;" nevertheless we need greater and more persevering endeavors in order to reach the desired

end, and to bring the undertaking into perfect shape. Therefore, we appeal, first of all, to our German fellow-citizens, and after them to all those who are interested in the development of the human race, requesting them to encourage our work by becoming members of the museum, as well as by gifts of money and relics.

We refer to the accompanying constitution, and hope for a large and liberal indorsement of our enterprise.

Not less welcome to us are all such objects as properly find place in our collection, and which the accompanying classified catalogue designates. In this respect we rely especially upon our numerous fellow-countrymen in foreign parts, who have the requisite facilities, by transmitting any kind of ethnological objects, photographs, pictures, models, &c., from the countries where they reside, to give a living evidence that they, realizing the intellectual endeavors of the fatherland, have also a warm heart for our cause.

And especially would we earnestly recommend the enterprise to the consuls of the German government and to its other foreign representatives, and beg them to work diligently for it. So also we propose it as desirable to organize in proper places local societies for the furtherance of our scheme. We look upon the formation of such societies as one of the principal duties of the managers, and we invite the foreign friends of the cause who may be so inclined to accept the honor of such an "agency," and to oblige the undersigned by informing them of the fact.

We indulge the hope that everywhere, in our country as well as abroad, friends of our work will be found gathered, who will assume the task of fostering and furthering the Museum of Ethnology, and who will gladly embrace every opportunity to favor us. Those who render especial service to the museum may be admitted to "honorary membership," or be named in a list of "patrons," and receive a diploma therefor.

Finally, we desire for the foregoing circular the widest possible publicity.

LEIPSIC, April, 1873.

Board of Regents:
- Prof. Dr. LEUCKART.
- Privy-Counselor PESCHEL.
- Doctor OBST.
- Consul-General GUSTAV SPIESS.
- Banker GUSTAV PLANT.

Board of Overseers:
- Prof. Dr. BRUHNS, *President.*
- Dr. OTTO DELITSCH, *Vice-President.*
- K. L. C. ROSENCRANTZ, *Secretary.*
- EMMERICH ANSCHÜTZ.
- AUGUST FLEISCHHAUER.
- Dr. GOLDSCHMIDT.
- GEORGE LAMPE-BENDER.
- GUSTAV MEYER.
- RICHARD OBERLÄNDER.
- Prof. Dr. STRÜMPELL.
- Prof. Dr. V. TISCHENDORF.
- Dr. VOIGT.

CONSTITUTION OF THE MUSEUM OF ETHNOLOGY IN LEIPSIC.

1. The association, endowed with incorporated rights under the name of "Museum of Ethnology" in Leipsic, has for its aim the systematic gathering of objects illustrating human nature and culture, and the fostering of the science of ethnology.

2. Any one may become a member by the payment of an annual subscription of two thalers. The payment of at least twenty thalers at one time entitles one to a life-membership. Those who have rendered especial service to the science of ethnology or to the museum may be appointed by the Regents to an "agency."

3. Every member is entitled to free admission to the museum, and to the use of the collection in conformity with the rules prescribed by the Regents, and to a voice and vote in the general assembly of members. Family-tickets are to be issued for members at reduced rates. Resignation may take place at any time. Those who remain in arrears after a month's notice will be dropped.

4. In order to foster and enlarge the influence of the museum abroad, "agents" will be appointed by the Regents, at designated places in Germany and in foreign parts, who are to hold the distinction of "honorary membership" and to undertake the task of representing the society.

5. The business of the society will be transacted by—

a. The Board of Regents;

b. The Board of Inspectors, (overseers;)

c. The general assembly of members.

6. The Board of Regents will consist of five members, who shall, from their number, elect a first and a second regent, a first and a second secretary, and a treasurer. The Regents will be chosen by the overseers annually from among the members of the society, and shall hold their office from the day of election until the next election. If a member of the Board of Regents withdraws in the mean time, the Overseers shall hold an election to supply his place.

7. All the members of the Board of Regents must reside in Leipsic or in its immediate vicinity. Their names will be published in the Leipsic Daily Journal, and in a German newspaper to be designated by the Board of Regents, and the publication in the first-named paper shall serve as their notice of election.

8. All orders and obligations shall be binding on the society if they have the name "Museum of Ethnology" attached, and the signature of one regent, of one secretary, and of the treasurer.

9. The "Board of Overseers" shall have the general supervision of affairs in conformity with section 8 of the law of June 15, 1868, and shall consist of twelve members, who shall be elected at the annual meeting of members, to hold office for three years, one-third to withdraw every year, the first two years by lot, afterward from the date of

election. Those withdrawing may be re-elected. The official year is reckoned from the close of one yearly meeting until the close of the next.

10. To the Board of Overseers, who shall elect annually from their number a president and secretary, are especially intrusted with—

a. The oversight of the transactions of the regents;

b. The auditing and approving of the yearly accounts;

c. The election of regents;

d. The previous approval of every expenditure which shall exceed $500, as well as the indorsement of commissions which shall exceed $250 annually;

e. The convocation and management of ordinary and extraordinary meetings of members.

11. Every regularly called meeting is competent to transact business, but for the adoption of motions respecting sections *c* and *d*, a majority of at least two-thirds of the members present is necessary.

12. The Board of Regents shall make a report annually at the close of the fiscal year, corresponding with the civil year, upon the condition of the affairs of the society, and send a copy of the same to each of the members at least two weeks before the annual meeting.

13. In the event of the dissolution of the society, its property shall go to the University of Leipsic.

Instructions for the "Agents" of the Museum of Ethnology.

§ 1. The authorized agents have, by § 4 of the statute, the duty of fostering and enlarging the museum.

§ 2. Their office shall be "honorary."

§ 3. They shall be appointed by the Regents properly organized.

§ 4. Their chief service shall be the enrolling of members and the soliciting and receiving of donations of objects and money for extending and improving the museum.

§ 5. They are likewise authorized to collect the contributions of members in their vicinity, especially all those living in our maritime towns and in transmarine countries, requested to take in charge consignments designed for the museum, and to forward them as soon as possible to their destination, and to apprise the Regents as soon as possible of any known opportunities of enriching the collection.

§ 6. The debts which the agents may incur through collecting, packing, and sending, &c., and any other authorized expenditures, shall be refunded. They are also entitled to pay, at the cost of the museum to mariners and other persons, a premium for relics, &c., not to exceed $10 per single object. For higher grants it will be necessary previously to consult the Regents.

§ 7. All members' subscriptions, or, if not collected, an account thereof, are to be sent at the latest by the close of the first half of the year to the treasurer of the museum at Leipsic, while any more important

gratuities that may be conferred, as well as gifts of objects, are to be sent to the order of the Regents as soon as they can be apprised thereof.

§ 8. The agents are further requested to send at the close of the year, and not later than the month of January, a catalogue of the members and benefactors living in their vicinity, and a list of contributions and gifts.

§ 9. Likewise the agents have the authority to issue to members receipts for contributions, tickets of membership, and annual statements of their accounts.

LEIPSIC, *April*, 1873.

By authority of—

THE REGENTS OF THE MUSEUM OF ETHNOLOGY.

For a more definite description of the objects which are desired for the "Museum of Ethnology," the Board of Regents beg leave to call the attention of its friends to the following summary, requesting them not to neglect the smallest thing, whose importance may depend not so much on the worth of the object itself, as upon the value which it may possess in the whole series, and upon the amount of its contribution to the completeness of the collection.

[NOTE.—The classes of culture-historical objects are arranged as nearly as possible in what Dr. Klemm considered to be the order of development, supposing the human race to have grown up from a condition characterized by the want of all things.—O. T. M.]

I.

OBJECTS WHICH THROW LIGHT UPON THE CONSTITUTION OF THE HUMAN RACE.

Skeletons.
Skulls, methods of measuring and apparatus used.
Pelves.
Single bones.
Mummies.
Brains, Inner organs, Embryological specimens, Parts of the body, Skin, } Preserved in alcohol or otherwise.
Teeth.
Hair.
At the same time not only must the human subject be regarded, but also the animals which are definitely related to man, as for example:
Paleontological remains.
Animal mummies.
Parasites.
Domestic animals, &c.
In order to render individual peculiarities of single men harmless, for the determination of characteristic [class] attributes, it is desirable to collect the greatest number possible of skulls, &c., of the same race.

II.

OBJECTS WHICH THROW LIGHT UPON THE HISTORY OF CULTURE OF THE HUMAN RACE.

1.—*Means of subsistence.*

Among which are to be reckoned not only—
Foods;
Drinks;
But also means of gratification, as—
Tobacco;
Other narcotics;
Spices and aromatics;
Perfumes, &c.

2.—*Fire.*

Fuel.
Fire, implements for kindling, as—
Fire-sticks;
Steel implements;
Stone implements;
Spunk, tinder, matches, &c.
Heating, burning, and cooking contrivances, &c.

3.—*Weapons.*

Stone weapons;
Wooden weapons;

Bone weapons;
Bronze weapons;
Iron weapons, embracing those for—
- Striking and throwing, as—
  - Sticks or staves;
  - Clubs;
  - Lassos;
- For cutting and thrusting, as—
  - Axes and hatchets;
  - Cutlasses;
  - Swords;
  - Knives;
  - Scythes;
- For sawing, as—
  - Fish-tooth weapons;
- For pricking or stabbing, as—
  - Lances and spears;
  - Rapiers;
  - Daggers, &c.;
- For shooting, as—
  - Missiles, slings;
  - Javelins;
  - Blowing-tubes and arrows;
  - Arrows and arrow-heads;
  - Bows;
  - Quivers;
  - Darting boards and straps;
  - Catapults; (?)
  - Cross-bows and arrows;
  - Fire-wreaths;
  - Fire-weapons of all kinds;
  - Balls and fire-arms.

Means of defense, &c.—
- Shields and bucklers.
- Hilts.
- Caltrops.
- Fetters.
- Pitfalls and snares.

Besieging apparatus.

Thereto also the raw materials, mineral, vegetable, and animal, are to be added, as well as the originals furnished by nature, such as—
- Drift pebbles.
- Pointed and perforated stones, ores, &c.
- Wooden hooks, clubs, &c.
- Teeth, &c., serving as models.

4.—*Tools and implements.*

Those for domestic purposes.
For every kind of handiwork.
For flint pecking and chipping, stone boring and polishing.
For tanning leather and making shoes, &c.
For agriculture.
For mining.
For fishing.
For hunting.
For horticulture.
For manufactures and industrial arts; out of—
- Stone.
- Wood and vegetable fibers.
- Bones and such like materials.
- Metals.

To these are to be added raw-materials and implements furnished by nature; also machines and their parts, for—
- Spinning, knitting, and weaving.
- Mealing.
- Grinding tools.

Apparatus and necessaries for scientific and industrial purposes, and those whose use is not known.

5.—*Clothing.*

Raw material, as—
- Wool.
- Hides and leather.

Animal and vegetable fiber.
- Bark and bast.
- Other materials.

Materials and products in the different stages of manufacture, as—
- Woolen stuffs.
- Silk stuffs.
- Linen stuffs.
- Cotton stuffs.
- Different varieties of, and mixed materials.

Articles of clothing, as—
- Aprons and girdles.
- Body-clothing—
  - Breeches.
  - Shirts.
  - Vests.
  - Jackets.
  - Coats for men.
- Outer wrappings and dress of women—
  - Bodices.
  - Laces.
  - Corsets.
  - Gowns.
  - Over-garments.
- Armor, mail, &c.
- Cloths.

Neck-kerchiefs.
  - Collars and capes.
  - Shawls.
  - Pocket-handkerchiefs.
  - Veils.
  - Towels.
  - Coverlets.
- Arm-clothing—
  - Sleeves.
  - Ruffles.
  - Gloves.
- Foot-covering—
  - Stockings.
  - Garters.
  - Moccasins.
  - Shoes.
  - Boots.
  - Sandals, &c.
- Head-gear—
  - Hats.
  - Caps.
  - Hoods.
  - Cowls.
  - Head-cloths.
  - Turbans.
  - Helmets.
  - Masks, &c.

Different parts of dress, as—
- Pockets and purses.
- Aprons, &c.
- Sewing and embroidery.
- Lace.
- Buckles.
- Buttons, &c.

Dolls in costume and lay-figures.

6.—*Ornament.*

Skin dyeing and tattooing.
Head-ornament, as:
- Wigs.
- Hair-decorations, (modes of dressing.)
- Hair-pins.
- Combs.
- Diadems, tiaras, coronets.
- Ear-ornaments.
- Nose, lip, and cheek ornaments.

Neck-ornaments—
- Neck-chains.
- Neck-rings and gorgets.

Breast-ornaments.
Arm-ornaments.
Finger-ornaments.
Leg-ornaments.
Toilet-articles—
- Brushes.
- Combs.
- Mirrors.
- Paints.
- Cosmetic and cosmetic boxes.
- Powder boxes and brushes.
- Soaps.

Fans.
Umbrellas.
Artificial flowers.
Feather ornaments.
Miscellaneous objects of ornament, made of—
- Mineral material.
- Vegetable material.
- Animal material.

7.—*Vessels, plates, and other objects for household-use, from animal material, from vegetable, as leaves, wood, bark, bast, &c., and from minerals, especially including—*

Stone vessels.
Clay vessels.
Stone-ware.
Fayence and delft.
Porcelain.
Glass.
Metal, &c., and embracing—
- Gourds.
- Nuts.
- Shells.
- Reed-tubes.
- Horns.
- Baskets.
- Woven ware.
- Boxes.
- Chests.
- Casks and the like.
- Cans.
- Pitchers.

Metals, &c.—Continued.
- Tumblers.
- Goblets.
- Beakers.
- Flasks.
- Plates.
- Cups.
- Bowls.
- Tureens.
- Pots.
- Jars.
- Pans.
- Knives.
- Forks.
- Eating-sticks.
- Spoons.
- Urns.
- Lamps.
- Candlesticks.
- Tobacco-holders.
- Tobacco-pipes.
- Miscellaneous plates and vessels, also the raw material out of which the objects have been made.

8.—*Dwellings, their appurtenances, and their ornamentations.*

House-furniture.
Building-materials.
Original models and designs—
- Nests of birds, insects, and other animal habitations.
- Pits.
- Caves.
- Huts.
- Tents.
- Dwelling-houses.
- Farm-buildings.
- Industrial and professional establishments.
- Villas.
- Castles.
- Palaces, &c.

Appurtenances of dwellings, as—
- Locks and keys, nails and screws.
- Windows, verandahs, roofs.
- Doors and hinges, &c.

Internal arrangements—
- Hearths.
- Kitchens.
- Living and sleeping apartments.

Outer ornamentations—
- Stucco.
- Mosaic.

All kinds of internal ornaments, as—
- Tapestry.
- Carpets.
- Curtains, &c.

Housekeeping articles, as—
- Furniture. } of guest-rooms.
- Hammocks. } of bed-rooms.
- Bedding, &c., } of eating-rooms.
- Implements and utensils of all kinds.

9.—*Games and playthings.*

Games for adults—
- Cards.

Games, &c.—Continued.
- Chess.
- Draughts, &c.
- Field-sports, &c.

Games for children—
- Dolls.
- Hoops, &c.

10.—*Vehicles and traveling-utensils.*

Water-vehicles—
- Rafts and floats.
- Canoes and models.
- Ship-models.

Equipments, as—
- Masts and sails.
- Rudders.
- Oars and paddles.
- Anchors.
- Outriggers.
- Cables, &c.

Miscellaneous objects pertaining to navigation and nautical life.

Land-vehicles and accessaries of journeys—
- Originals, models and drawings of—
  - Palanquins and the like.
  - Wagons.
  - Sleds.
  - Snowshoes.
  - Skates.

Riding and traveling utensils—
- Whips and girts.
- Harness.
- Saddles.
- Stirrups.
- Spurs.
- Bits.
- Horseshoes.
- Trappings.
- Bells.

Hunting-implements.

Implements for journeys on foot.

Miscellaneous objects connected with—
- Postal service.
- Railroading.
- Telegraphy.

11.—*Musical instruments.*

Cymbals, (castanets.)

Rattles.

Clappers.

Drums.

Bones.

Wind-instruments, as—
- Panpipes.
- Fifes.
- Flutes.
- Horns.
- Trumpets.
- Trombones, &c.

Stringed instruments.

Reed-instruments.

Rebecs.

Various other instruments.

12.—*Sacra.*

Images of holy persons.

Images of gods.

Amulets.

Garlands.

Rosaries.

Exorcising cymbals and drums.

Charms and "medicine" cases for witchcraft.

All objects used in religious worship—
- Altars.
- Sacerdotal dress.
- Croziers.
- Mitres.
- Church and temple furniture.
- Censers and incense.
- Fetiches.
- Teraphim, &c.

Models and drawings of—
- Sacrificial places.
- Temples.
- Churches.

13.—*Fine arts.*

First efforts of primitive peoples.

Works of architecture.

Works of sculpture and engraving in wood, bone, ivory, shell, horn, stone, clay, and metal.

Works of painting—
- Portraits.
- Designs.
- Reproductions, &c.

Casting of metals.

Mosaic and gem cutting.

Productions of lesser arts and of art-traffic.

14.—*Writing.*

Writing-material, as—
- Styles.
- Pens.
- India-ink, paints, and colors.
- Inkstands.
- Rulers.
- Seals.
- Paper.
- Parchment.

Rock sculptures and inscriptions.

Inscriptions on—
- Stone.
- Clay.
- Metal.
- Paper.
- Leaves of plants.
- Parchment.

Alphabets and alphabetic systems.

Presses and books.

15.—*Measures, weights, coins.*

Measures—
- Counting and keeping tally.
- Notched sticks and tallies.
- Measuring-rods.
- Scales and weights.
- Measuring-instruments in general.
- Time-pieces.

Money—
- Coin.
- Substitutes for coin.

Money—Continued.
- Paper-money.
- Certificates of indebtedness.

Medals, badges, and other outer decorations.

16.—*Public life.*

All objects which relate to judiciary and police affairs.
Medical practice.
Eleemosynary and reform.
Birth and lineage.
Baptism.
Marriage.
Education.
Burial and sepulchers.
Feasts, &c.

NOTICE.

The objects mentioned in the foregoing catalogue are designed to exhibit human nature and culture in all parts of the earth, in historical as well as in prehistoric times.

Where the obtaining of originals is impossible or impracticable, as, for example, of buildings, &c., let proper models, casts, other imitations, drawings, photographs, &c., be taken. (It is exceedingly important to have photographs and truthful sketches of men in the performance of all the occupations which designate culture.)

Also, in general, the raw material is desirable (as already mentioned in different places above) out of which the different objects are made; also the finished and unfinished products of industry and handicraft.

Of drawings, especially those of human subjects, it is desirable to take as many as possible of the natural size, and to state whether they were taken immediately from the original subject or were otherwise procured.

Drawings intended to illustrate races of men should exhibit both the full face and the profile.

The object and the place of its discovery should be accurately noted; also the people or race from whom it is procured or by whom it is used.

It is further necessary regarding discoveries, especially prehistoric discoveries, accurately to describe the nature of the places where they are made so far as practicable, and especially to state the kind of soil when feasible, accompanied with specimens or proofs. Generally careful and diligent attention must be paid to the whole geological and topographical surroundings, likewise to the depth at which the discovery was made, the time, as well as to other attending circumstances; to which are to be added accounts of objects which are found lying with them or near at hand, as, for example, of human relics, bones of animals, vegetable remains, weapons, tools, vessels, objects of dress, ornaments, &c.

And, further, great attention should be paid to ancient human habitations and settlements, to cave-dwellings, and pile-structures, and to whatever is in relation therewith; also to graves, burial-grounds, monumental stones, &c., with the accompanying relics of ancient human and animal bones, old weapons and tools, old vessels, urns, and like objects.

Likewise is to be associated with the museum a library, which shall

embody anthropology and ethnology in the widest sense, as well as the related sciences of geography, travels, philology, general psychology, &c.; therefore we recommend the enterprise to the favorable attention of distinguished authors, publishers, curators of libraries, and of scientific associations.

ANTIQUITIES OF UNION COUNTY, ILLINOIS.

By Thomas M. Perrine.

A few days ago, I, with three others, citizens of this town, engaged in exploring one of those mounds located on the Running Lake, about eight miles from Anna, Illinois. As there is nothing unusual in the form of this mound, it needs no description. About fifteen years ago it became necessary, in repairing a graded way across the lake, to remove a portion of the mound, so at this time there is but a small portion of it left. This portion has often been dug into by the curious, but without obtaining any result worth mentioning. We were fortunate enough, however, to get some very fine pieces of pottery, representing in their formation turtles, fish, &c.; but imagine my astonishment when my spade uncovered a white "porphyry" stone, of forty pounds weight, which had been carved from the rough into an idol, or it may have been intended for a piece of statuary. It is represented in a sitting position, with the left leg drawn under the body, tailor-like, while the right leg is drawn up to the thigh, supporting thereon the right hand, with the elbow projecting down on the outside of the thigh, forming a very natural arch of 45°. It was undoubtedly intended to represent the human form in health, and clothed with muscle and skin. The face is expressive, finely chiseled, and has a resemblance to a photograph I have seen of the Sphynx. It is true to anatomical proportions, and perfect in all its parts. From the top of the head along the line of the sagittal suture to the chin, it measures 16 inches; from the point of one shoulder to the other across the back, 9 inches; and the same across the breast or front. The length of arm, fore-arm, and hand to point of middle finger is 11 inches; from ear to ear, across back of head, 8 inches; across the hips, 9 inches. The leg, thigh, and foot measure 11½ inches; the length of face, from the chin to what represents the hair, is 5 inches; around the neck, under the chin, 15 inches; the height in sitting-posture is 13 inches. If 11½ inches be added for inferior extremities, the height would be 25½ inches if extended. From the spine in the center of the back a line or groove is cut, running to the right and left, and extending to the cranium or crown of the head. The ears, eyes, nose, chin, and contour of the head, as well as the whole image, is perfect, and no way mutilated by time—the stone being so very hard.

But I am making my letter too long. Inclosed I send you photographs. The photographs are not good, but they are the best I can get in this place. I will write to you if anything more of interest is found.

ANTIQUITIES OF KNOX COUNTY, INDIANA, AND LAWRENCE COUNTY, ILLINOIS.

By Dr. A. Patton.

The early history of Vincennes is involved in much doubt and uncertainty. No records or monumental remains have yet been found indicating the precise time when this rather ancient place was first settled.

The Piankeshaw Indians had a village here, some remains of which are still found in making excavations for wells and street-improvements. But there are unmistakable evidences of a more ancient and no doubt a more civilized people than the Indians having inhabited this town. Upon the high elevation of land that almost surrounds the beautiful diluvial prairie on which the city of Vincennes is built, there stand in full view of the town three of the most beautiful mounds in the West. Until very lately, the largest of these was considered a natural formation, but few persons suspecting that it was an artificial mound. It is named Sugar Loaf Mound. Its height is nearly 70 feet, the circumference at the base 1,000 feet. It stands on a promontory, which no doubt was once washed by the Wabash River. The observer from the top of this mound can see not only the entire city lying in the smooth level valley, more than 100 feet beneath, but other mounds, which are about one mile distant from each other. The only exploration that has been attempted of this large mound was done under my direction in the month of June last. A shaft 4 feet square was sunk in the center of it, and carried to a depth of 46 feet. The first observation was the character of the material composing the structure. It was found to be a siliceous sand, very slightly mixed with alluvial deposits. Professor Collett considers it a fair specimen of the "loess." There is a marked difference, however, between the appearance of this earth and any found in the vicinity of the mound. A brick-manufacturer insisted that he could show us earth precisely like it, but upon comparing the two specimens it was evident that there was no similarity, as he admitted himself. All the other mounds in this neighborhood on the east side of the river are found to contain precisely the same material, but so far we have not been able to ascertain the locality from which the material was obtained. Evidently, it was brought from a considerable distance. The character of the earth composing this mound presenting such a striking difference from any near it, was sufficient of itself to demonstrate that the mound was constructed by human hands, and its great size and symmetrical form indicated skill and intelligence. The explorations, though not attended with any striking developments in archeology, revealed other evidences of art in the construction of the mound, which left no room for further doubt as to its origin. At 10 feet below the surface, bones were found, but which were so tender that but very small fragments were secured. Immediately below this layer

of decayed bones, a layer of ashes and charcoal was found. Thirty feet below this we reached bones, charcoal, and ashes again. The bones here were very brittle, and could not be handled. A bed of calcinated clay was then entered, which was too hard to excavate with the implements we were using. This we supposed to be either a sacrificial altar or a place that had been used for cremation-purposes. No pottery or implements of any kind were found in the shaft we sunk, which may only indicate that this was not a burial-mound and was erected for some other and higher purpose; perhaps for a place of worship, or for an observatory, or for military defense. Many varieties of small shells were found, some of the specimens having no living representatives in this locality or any climate as far north as this. Vincennes is situated in 38° 43′ north latitude and 87° 25′ west longitude, and 450 feet above the level of the sea.

Pyramid Mound is one mile south of the Sugar Loaf Mound, and is named from its form being pyramidal. Its height is 43 feet and circumference at base 714 feet; the top is 15 feet wide and 50 feet in length. I have had this mound opened in several places, but no extensive or systematic explorations have been made of it, owing to objections by the owner. The first examination was attempted in January, 1872, by Professor Tenny, of Williams College, Massachusetts, and myself; but the weather being very cold, our excavations were not made sufficiently deep to determine the character of the mound any further than its being certainly the work of art, and that it had been used as a burial-place either by the mound-builders or the Indians, as we found parts of a human skeleton only 3 feet below the surface at the top of the mound. The long bones were in a fair state of preservation, but the cranium was broken into fragments. In June and July last some imperfect examinations were made by excavations extending 4 or 5 feet in depth. An abundance of human bones were found, but all were very rotten. Two or three arrow-heads were obtained, but no pottery or other relics were found.

The North Mound has never been examined except by curiosity-hunters. Bones were found, but I can give no information in regard to them. The height is 36 feet; circumference at base, 847 feet. One mile north of this mound is another beautiful one, though not more than 25 feet in height and 400 feet in circumference at base; it has never been examined. There are twelve small mounds within the city-limits, situated near the bank of the river, but above the overflow. One or two of these mounds have been explored, and human bones in large quantities have been exhumed. There is a mound three miles below the city, the height of which is 12 feet. The stump of a large walnut-tree 4 feet across the center is standing on the top of it. The tree was removed about twenty-five years ago; it is impossible to determine the age of the tree by the rings at present. I had an excavation made into this mound, but nothing of special interest was revealed except large quantities of broken

pottery, several flint arrow-heads, and one stone knife having the form and size of an ordinary knife-blade, and very sharp on both edges. There were bones, but too tender to handle. Bones and pottery were found under the stump. I send specimens from this mound marked "Bottom Mound." Prof. John Collett, who made a geological survey of Knox County in June and July last, thinks there are 300 ancient mounds in this county.

The mounds in Lawrence County, Illinois, have produced much better results in an archeological aspect than any examined in Knox County, Indiana. I had a very large mound excavated that is situated on Mr. Antone Ritchirdville's farm, one mile from this city, from which was obtained one cranium in a fine state of preservation, and which presents some very interesting points for the consideration of the ethnologist; but as it is to be submitted to the examination of an expert, I will give no descriptions and express no opinion of it. I send with it one femur and one humerus, a tibia, fibula, and ulna. There was found near this skeleton, which was about 4 feet below the surface, a very large shell, a *Pyrula caniculata*; it is 11 inches long, and 6 inches at the widest point. There were pieces of well-polished stone, one of which has a hole through its center. There is a white-oak tree (*Quercus alba*) growing on the mound, under which were found fragments of crania and some pottery. It seems to have been burned until charred.

There are fifteen mounds standing near each other, forming a circle, with one in the center, situated about 400 yards from the river, in the valley, two miles southwest of Vincennes, where there is an annual overflow. They are constructed of materials obtained around them, and contain nothing of interest so far as examined, with the exception of a skeleton, which had been inclosed in a rough plank coffin, and was evidently an intrusive burial by our own people, probably a boatman. I send the cranium merely for comparison with the others. I have had five mounds opened that are situated on the Embarras River, near Brown's old mill, in Lawrence County, Illinois. They are eight miles southwest of this place, and have proved rich in relics. The cranium marked "Brown's Mill Mound" was obtained by Mr. Carl Busse, who kindly presented it to our public-school cabinet. It presents some points of scientific interest. The skeleton was found in a sitting-posture. Near it was found a beautiful pipe, also a bunch of long straight hair bound together with a deer-skin thong, and having wrapped around it a piece of cloth that is curiously woven, and once had bright colors, but has faded considerably since it was removed from the mound. There were twelve skeletons removed from this mound, but the crania were all rotten, with the single exception of the one I send to the Institution, In the five mounds lately opened there was nothing of interest discovered, with the exception of human bones, very much decayed. In the first one there was a single skeleton, but the bones literally crumbled into dust when attempted to be removed. In the second, there were

four skeletons; in the third, three; in the fourth, four; and in the fifth, not a bone was found. Several pieces of arrow-heads and some very hard pottery were found. Some of the pottery found in these mounds was ornamented in a manner that indicated some skill and appreciation of order in arrangement. The ornamented pottery was found in the mound from which the Busse cranium was taken. This mound is 12 feet in height, and 60 in diameter at the base, and nearly the same on the top.

The skeletons in all these mounds were found from one to four feet below the surface. The bones nearest the surface were invariably in the best state of preservation, while those at or near the bottom were completely decomposed. In some cases, the form and appearance were natural, but the moment the earth was removed from them, and an attempt was made to remove them, they fell into dust. Others presented the appearance and consistence of soft chalk, a slight pressure between the fingers causing them to crumble.

I have opened two mounds in Vincennes recently. The first is 110 feet in circumference at base, 45 feet diameter east and west, 6 feet high. A trench 4 feet wide was cut more than half across it, extend ing to 1 foot below the base of the mound. It was composed of the ordinary surface-loam to a depth of 6 feet, where a layer of very soft tenacious grayish clay was reached, which was only 3 inches in thickness, and rested immediately upon the top of the ground. This layer of clay formed the base of both these city-mounds, as it did of all the mounds examined in Illinois. There was nothing of interest found in either of them; no bones or pottery, ashes, coal, or relics of any kind. These mounds are near the one described by William Pidgeon in 1867, in which many bones were found.

Although the mounds in and around Vincennes have so far furnished no interesting relics or important contributions to science, yet some doubtful questions have been solved, with a fair probability of a solution being given to other problems, which may prove of some value to ethnology. The artificial origin of our large mounds has been fully demonstrated, which has heretofore been denied by some and doubted by many. It is certain that the material of which the large mound is composed is different from any in the neighborhood, and thus the shells found in the large mound belong to a warm climate, which indicates either that the mound was constructed when the locality enjoyed a warmer climate than at present, or that they were brought from the south. The study of these facts may lead to a solution of some difficult and obscure questions. By carefully examining the calcinated clay in the large mound, a question about which there is some controversy may be settled, as to whether these burned-clay structures are for sacrificial altars or cremation-purposes. That the age of these mounds can and will be determined by scientific investigations, I think very prob-

able, and we may yet ascertain who were their builders, and for what purpose they were made.

It is to be regretted, however, that more extended and more thorough examinations of the many mounds in this and Lawrence County, Illinois, have not been made, as this region certainly presents a most favorable field for ethnological investigations. From the great number of mounds in this locality and the very large size of some of them, together with the relics already found, it may be supposed that the Wabash Valley, and especially Knox County, Indiana, and Lawrence County, Illinois, were once densely populated by that ancient race of people whose history is so veiled in obscurity that it is difficult to determine who they were or whence they came. It is very probable that there have been many intrusive burials in the mounds that have been examined, and it is, therefore, difficult, but very important, to determine questions of race by the careful inspection of the crania and the relics removed with them. If a well-preserved cranium could be discovered near the center and at great depth in any of the larger mounds, it might be taken for granted that it belonged to the original race of mound-builders. It is, therefore, desirable that further explorations should be made in the Sugar Loaf and Pyramid Mounds. By tunneling horizontally, commencing near the base and proceeding toward the center, using strong timbers for protection against the falling earth, discoveries of great scientific interest might be made, and I would be very much pleased to see a work of this kind undertaken by some competent person. The beautiful little valley in the center of which Vincennes now stands was, doubtless, once a great city, occupied by the mound-builders, and their villages and farms were scattered over the country as ours are at present. There is a line of natural elevations almost surrounding the valley on the north, south, and east sides, having the river on the west. There is a low piece of land lying between the southern mound and Bunker Hill of about 900 yards, and from Bunker Hill to the river there is an opening of about a mile, in which, however, there is one mound still standing; and from the frequent findings of pottery and stone implements between these points, it is very probable that there was once an artificial embankment from Bunker Hill to the river, and from Bunker Hill to the southern mound. In addition to this, Professor Collett has expressed the opinion that there is a continuous line of artificial defenses extending from the river above Fort Knox around to Bunker Hill, nearly a mile in the rear of the line on which the mounds are situated. Professor Collett is a very accurate observer, but his time was too limited to enable him to make a thorough and satisfactory examination. It has been supposed by many observers that the Wabash River once occupied the entire plain between its present western shore and the line of the elevations on which the large mounds are situated; and that, when those mounds were first erected,

they were immediately on the bank of the river. But while it is, no doubt, true that the river once washed the base of the promontory on which Sugar Loaf Mound now stands, it was doubtless long anterior to the time when that great mound was erected. The small mounds in the city-limits stand on land that, according to that theory, must have been under water when the great mound was being erected, but which is now above overflow. Either this view is incorrect, or the city-mounds were built long after the large mounds were, and by a different race of people. It is claimed by some ethnologists that the mounds erected on low and overflowed lands were built by a race of people called fishermen, who inhabited this country about eight hundred years ago. But the data upon which these theories are based are of so doubtful a character and so defective that it will require other discoveries and more accurate investigations to solve these great questions. It is for the solution of problems like these and others of still greater importance to ethnological science that earnest and faithful inquiries after truth will follow the pick and shovel in excavating the works of these mysterious people. It is no idle or unmeaning curiosity, or love of sordid gain, or desire for a little notoriety, that prompts investigations like these, but a refined and sacred love of truth and a noble desire to add to the great treasury of useful knowledge and to aid in perfecting sciences that are now in their infancy and struggling for existence. Some strictly practical men may claim that such investigations are useless, and time not well spent; but they forget that all truth is divine, and that many seemingly unimportant facts are necessary to establish a principle, and that principles make up great systems, and that systems make worlds, and worlds a universe which is presided over by one Allwise Being, and that all truth and the world's activities are emanations from God; and as we learn more of nature's great laws and solve problems in ethnological or any other science, we learn more of our Creator and his laws. It is very true that the few simple isolated facts that may be gathered by local ethnological observers would be of but very little value if viewed separately; but when they are combined and properly arranged with other discoveries and developments that are being made all over this country and Europe, great problems may be solved, important principles unfolded, and the science perfected.

As these city-mounds are erected on land that is above overflow, and as but few of them present any evidence of their being burial-mounds, it may be supposed that they were erected by the same race and for the same purposes as were the large mounds on the hills; and all are, no doubt, ancient mounds in the strictest sense of that term; and although scarcely anything has been found in any of them to indicate their nature or origin, yet they are not the less interesting to the student of ethnology.

MISCELLANEOUS CORRESPONDENCE.

EXPLORATIONS ON THE WESTERN COAST OF NORTH AMERICA.

By William H. Dall,
Of the United States Coast Survey.

I am glad to be able to announce that we have returned safely from a six months' cruise in the Aleutian Islands, after a satisfactory season's work. We have chiefly been employed in the determination of astronomical positions, the magnetic declination, deep-sea soundings, the survey of a harbor for the landing-place of the Japanese cable, if it should be determined to take it via the Aleutian Islands, hydrographic notes of various importance, and the continuation of our meteorological, current, and sea-temperature observations of previous years. Our field of work has been between Attoo, the most western island and point of the United States possessions, from island to island, through the chain, to the Shumagins.

Many of the islands were found to be several miles in error in their position, and the magnetic declination had decreased without exception, in its amount of easting, since the last observations were taken, from twenty to thirty years ago. The difference averages 2° 30′, but in some cases amounts to 6°. Our current and temperature observations confirmed those of previous years. We succeeded in finding a good harbor for the cable on the island of Kyska, and thoroughly surveyed it. Our soundings put an entirely new complexion on the western half of Behring Sea, where we obtained no bottom with a mile of line, quite close to the islands. We found the deposition of "recent chalk" mud going on at a depth of 800 fathoms—a fact of some importance, as it has not previously been reported on the Pacific side of the continent. We determined the boundaries of the Saunakh reefs, and the non-existence of the Bogostoff reef, both of which were of considerable importance to navigators.

In our leisure, the work of collecting specimens of prehistoric remains and objects of natural history was energetically prosecuted, resulting in the accumulation of eighteen boxes of specimens, which will be forwarded to the National Museum at the earliest opportunity. In prehistoric specimens, our results were of the greatest interest, and I feel assured of more value than any ever obtained in this region before. We

obtained thirty-six prehistoric crania, some two or three hundred bone and stone implements, remains of mummies from burial-caves, and two large cases of wooden carvings, masks, &c., deposited with the dead. I will write more fully as to the circumstances under which they were found at a future time. The boxes, which will be shipped as freight in a few days, have contents as follows:

Kegs 1 and 3 contain fish and miscellaneous alcoholic specimens.

Keg 2 contains skull and skin of an unknown species of seal, and an enormous crab from Adakh Island.

Box 1 contains dry sponges from Unalashka.

Box 2 contains sponges from Attoo.

Box 6 contains bones of whales, stone lamps, and other heavy prehistoric remains and rocks.

Box 8 contains prehistoric crania from caves on Atka Island.

Box 9 contains porpoise skeleton and one box of stone implements.

Boxes 11 and 12 contain crania from Amchitka, Adakh, Unalashka, Unga, &c.

Boxes 13 and 14 contain wooden carvings from caves, Unga.

Of these boxes, 1, 2, and 9 I should like to have kept intact (except taking out the prehistoric specimens from box 9) until my return. I should like to have the alcoholic specimens, not vertebrates, in the three kegs also taken care of until I may be able to overhaul them myself. It would be better to have them placed in some receptacle less liable to evaporation than the kegs until then. The other specimens will be sent as soon as they can be repacked.

Our collection of natural history is very valuable. It contains more material for the determination of geographical distribution and specific development than has ever been sent from the west coast before. I am consequently anxious that none of it should be lost to science. Our plants I sent direct to Professor Gray, as they would not bear delay.

I trust you will be pleased with the ethnological material, which excels in quantity and variety all collections yet made in that region.

I have before me one more season's work, in which I hope to supply many deficiencies and enlarge the boundaries of the region investigated. In the spring of 1875, under Providence, I hope to return to Washington, and settle quietly down to study, as I think that seven years of one's life are quite enough to be devoted to field-work in such an inaccessible region.

San Francisco, Cal., November 28, 1873.

CORRESPONDENCE RELATIVE TO THE DISCOVERY OF A LARGE METEORITE IN MEXICO.

Letter from William M. Pierson, United States vice-consul, Paso del Norte, Mexico, to the Department of State, Washington.

My attention of late has been drawn to the famous Sierra Madre, (Mother Mountains,) which are said to be the most prolific in rich gold and silver mines of all the mountains in the State of Chihuahua, from the fact of a very singular and large piece of meteoric iron having been discovered by a party of Mexicans while excavating in the ruins of the Casas Grandes, (great houses,) measuring 2 feet 6 inches square, and weighing, as is supposed, over 5,000 pounds. This particular portion of the Sierra Madre is located one hundred and fifty miles distant, and almost directly south from this city, in parallel 30.

"There is a tradition among the Pueblo Indians (town Indians) that the Montezuma tribes came from the extreme north in ancient times by gradual immigration, and settled at various points at intervals, until they arived at and built the city of Mexico. The truth of this tradition is verified by the plain trace of old ruined cities, built of adobe-brick, and extending from New Mexico and Arizona south to the city of Mexico. In the Gila Valley, Arizona, these immigrants appear to have halted, built a city, recuperated, raised a sufficient quantity of corn and beans, and then immigrated some four hundred and fifty miles farther south to the great plain under the foot of the Sierra Madre, in the State of Chihuahua, where another halt was made, another city built, and the same routine of recuperation and raising of corn and beans, preparatory for the march on to Mexico, was gone through with.

"The ruins of the Casas Grandes on the Gila River in Arizona show plainly that at one time a numerous and industrious people dwelt there, and at this day, from the ruins, the structure and plan of the city is discernable. Large rooms were built for a common depository of grain for the use and benefit of the public. The great ditch by which the water of the river Gila was turned out on the plain to irrigate, for the purpose of raising grain, is still plainly traceable; while the whole plain for miles around is profusely strewn with broken pottery, on which the devices and painting exactly correspond with that on the pottery manufactured by the Pueblo Indians of Mexico at the present day. These remarks will apply to the whole chain of Casas Grandes now in ruins, south from New Mexico and Arizona to the city of Mexico. It is a well-known fact that when the Spanish discovered Mexico, as far north as Santa Fé the country was settled in all the large and fertile valleys by Pueblo or town Indians, who lived by agricultural pursuits, planting corn, beans, and pumpkins, and constructing and living in large towns, built with the adobe-brick, the same as are now used throughout all Mexico; and that the Montezuma Indians possessed large amounts of the

precious metals, which reason teaches us must have been obtained from the surface of the earth. Even in our day, it is a well-known fact that over $125,000 in gold was taken from the surface on Antelope Hill, Arizona, ten miles from water, all picked up by hand on top of the ground. One of my own well-known friends was a participant in this gold-picking from the surface on Antelope Hill. (See J. Ross Browne on Mineral Resources of the United States, pages 466, 467.) So far as the American miner has prospected, he has found it to be a never-failing fact that near all the Casas Grandes, on the chain of immigration of the Montezumas from north to south, there exist rich gold and silver mines.

"There is a small Mexican town, called Casas Grandes, located at the foot of the Sierra Madre, one hundred and fifty miles south from this city, and near to the old ruins of the Montezuma Casas Grandes, in which there lives a brave and hardy race of Mexican mountaineers, who have braved the inroads of the indomitable Apache, and have set his malice, skill, and cunning at defiance from time immemorial. Some three or four years since, a party of these Mexican mountaineers, as a matter of curious speculation, commenced excavating in the old ruins of the Montezuma Casas Grandes, each man drifting into the old ruins at separate and several points. One, Teodoro Alverado, more fortunate than the others, drifted into a large room, in the middle of which there appeared a kind of tomb made of adobe-brick. Curiosity led this bold knight of the crow-bar to renew his excavations; and when he had reached the middle of this tomb, he there found this curious mass of meteoric iron referred to in the fore part of this dispatch, carefully and curiously wrapped with a kind of coarse linen, similar to that with which the Egyptians inclose or wrap their mummies. The excavators were now all summoned to view the curiosity. One anxious spectator, with more inquiry and ambition than the rest, gave this mass from the skies a vigorous blow with his crow-bar, whereupon it grave forth a loud and hollow sound, much resembling a church bell on a funeral occasion, which struck these honest savages with holy and reverential awe. An adjudication now immediately took place as to whether all the knights of the crow-bar should have a *pro-rata* interest in this interesting specimen, or whether the discoverer should own it in fee-simple. After due and mature deliberation, it was decided that, whereas each and every excavator had dug or drifted his own shaft according to his own notion of loss or gain, separately, therefore be it adjudged and decreed that Teodoro Alverado, the discoverer, do own the said meteoric mass in fee-simple. Twenty-six yoke of sturdy oxen were mustered, and as many or more strong log-chains, and, with this force and tackle, the monster meteorite was hauled on the ground to the modern town of Casas Grandes, and deposited in the street, in front of the discoverer's door. Alverado and his neighbors at first fixed a most fabulous value upon it, but after the lapse of years, both the novelty

and the reverential awe having subsided, and Alverado, like many of his peculiar race, feeling the stern hand of poverty pressing heavily upon him, has expressed a willingness to sell it for a reasonable price. Mr. Ernest Angerstein, a wealthy merchant of this city, has an agent (Mr. Leroy) living at the said modern Casas Grandes for the purpose of purchasing grain, and who has resided there for many years past, from whom I have gathered much information herein stated, although the main facts are widely known throughout the country; yet, Mr. Leroy having been an eye-witness, has furnished me several items in the *minutia.*

"The aforenamed Angerstein, Leroy, and myself have made up the necessary funds to purchase this rare and novel specimen, making it a mutual adventure, and have started a large mercantile wagon capable of carrying 10,000 pounds to transport it to this city. Our intention is to secure it for the admiration of the curious and the lovers of science. We shall have it safely lodged in the consulate within fifteen days from this date.

"The Apaches are now at war with the Mexican government, but some six years prior to this date they were at peace. This particular locality of the Casas Grandes, or, I should say, the Sierra Madre, is one of the Apache strongholds, and during the aforenamed period of peace the Apaches used to come down out of the mountains every Saturday to the modern Casas Grandes to trade with the Mexicans. They brought nuggets of gold from the size of a pea to a walnut, and exchanged them for powder, lead, and blankets. They must have known of gold-fields in the mountains similar to those of Antelope Hills herein referred to, and the ancient gold-fields known to the Montezumas.

"The Sierra Madre herein referred to are with one accord conceded to be by the best informed Mexicans the richest in gold and siver mines of all the mountains in the State of Chihuahua. The natural inquiry will be, Why, then, do not the Mexicans work these mines? The true reason and answer is, the peculiar form of the mountains, connected with the bravery of the warlike Apache, has heretofore been a complete bar, and prevented the most determined Mexicans from locating and working these mines. Then, again, the Mexicans are a weak and primitive people; for instance, their cart-wheels are cumbersome trucks of wood; the yoke for their oxen is a straight pole, placed across the forehead and lashed to the horns with strips of rawhide; their plow for tilling the soil is nothing more than a crooked stick of wood. I assert it without fear of contradiction, that in all of this Rio Grande Valley in my consulate, which is so famous for farming, there are not three iron or steel mold-board plows in use, nor any kind of a plow, except the crooked wooden stick.

"The Mexicans at the modern Casas Grandes are the bravest of their race, and they have all they can do to maintain themselves in the plain at the foot of the mountains; they have never been able to maintain themselves up in the mountains for any permanent purpose."

The foregoing letter was referred by Hon. William Hunter, Assistant Secretary of State, to the Smithsonian Institution. The following is the reply of the Secretary, Professor Henry:

"We have just received your very interesting letter of April 2, containing a specimen of meteoric iron, accompanied by the communication of Mr. W. M. Pierson, vice-consul of the United States at Paso del Norte. There can be little doubt that the specimen is from a meteorite, but to settle this point beyond controversy we shall have it carefully analyzed. The facts mentioned in the communication are very interesting; and, if the State Department has no objection, we would be pleased to publish it in the appendix to the next report.

"It would appear from observations that, on some occasion in the history of the globe, a shower of immense meteors fell upon the region where the meteor in question is found. The great meteorite at the Smithsonian Institution came from Tucson, and we have heard of a number of others of large size that came from the same locality. Large meteorites are of great interest to the science of the day. They all exhibit the appearance of having been subjected to an intense heat; and what is still more wonderful, in some of them, at least, is found condensed within the pores of the material a large quantity of hydrogen-gas, indicating that they have in some portion of their past existence been in an atmosphere of this material.

"It would give us great pleasure to subject a portion of the meteorite in question to an investigation in regard to its gaseous contents; and if the gentlemen who own it will present it to the Institution, we will cheerfully pay the expense of transportation, and forever associate their names in the history of science with the specimen, and with the results of any experiments that may be made in regard to it."

ON THE HABITS OF THE BEAVER.

By Felix R. Brunot, *of Pittsburgh, Pa.*

While visiting the Shoshone and Bannack Indian reservation in Western Wyoming Territory last September, I saw at the saw-mill a cotton-wood log which had been cut down by beavers, (*castor*,) and which is 2½ feet in diameter at the butt where the cutting was done. Whether you have anything of the kind at the Smithsonian Institution I do not know. The time will probably come when such tangible proofs of the rare industry and curious habits of the beaver will be unattainable, and people will be loth to credit the facts in regard to them.

Mr. S. G. Goodrich, in his popular work, "The Animal Kingdom," quotes the traveler Richardson as saying on this subject, "The largest tree I observed cut down by them was about the thickness of a man's thigh, that is, about 6 or 7 inches in diameter; but Mr. Graham says that he has seen them cut down a tree that was 10 inches in diameter;"

and the author adds, "This is no doubt an exaggeration, or at least very uncommon."

Captain Bonneville tells of having seen trees cut by beavers, which were 18 inches in diameter, as something marvelous, but this one at the Shoshone agency is a foot larger. If I am not mistaken, Washington Irving also expresses doubts, on the authority of Captain Bonneville, as to whether the beaver exercises any instinct, or judgment, if you please, in cutting the trees in such a way as to drop them into the water. I think he says that he saw some or many trees which had fallen to the shore-side, and from this fact reaches his conclusion that the direction in which the trees fell was a matter of accident.

I was for a day or two on the bank of Wind River, some forty miles from the nearest settlement, and where the beavers are quite abundant, and examined a cotton-wood tree 18 inches in diameter, on which they were nightly at work. It was just about ready to fall, and was being cut so as to render its fall in any other direction than toward the water impossible. This and the remembrance of Captain Bonneville's doubt led me to look further, and I found within a distance of 300 yards of the shore-line five other trees, nearly as large, which had been dropped into the water, and one other about 10 inches in diameter, which had been partly cut all around, but much more deeply on the water-side. The fallen trees were in a quick turn of the stream, where swift deep water swept along the shore, and the stumps showed the deepest cut in each case next to the water.

These trees were not cut for the purpose of making a dam, but for a winter-store of food, which the bark and twigs furnish, and they are dropped into the water to be there kept in a tender and palatable condition for their owners. Some further examinations showed me that there were other stumps of trees which had been cut off by the beavers a short distance from the stream, too far off to have been intended to reach the water, and these seemed to have no uniformity of direction in their fall. Is it not probable that these and other trees not dropped into the water are cut during the summer for immediate consumption, and give no proof whatever that these wise "fellers" do not know exactly what they are about, but to the contrary?

ON A NATIONAL LIBRARY.

Letter from W. S. Jevons, of Owens College, England.

When I returned from our long vacation, I found that you had been so good as to remember our desire to possess the "Smithsonian Contributions to Knowledge" in our library at Owens College. The librarian has, I believe, forwarded the formal acknowledgment of their receipt; but, both by desire of our principal and also of my own inclination, I write to express our warm thanks for so valuable a present to our library.

I have already read the larger part of the report for 1869, and some of the pamphlets, which give me access to papers not previously within my reach, but of which I had heard something.

We hope to receive future reports, although we can hardly hope to make adequate return. The librarian has already sent our calendar and catalogue of our library. I am also about to send to your London agent a set of my own publications, as I much desire that they may have a place in the Smithsonian library, which, as I learn from the report, appears likely to become the great national library of America.

I trust that the design may be carried out of erecting in America a library of unlimited extent, and of all-comprehensive character, which may, in course of time, embody the whole literature of the world as far as possible. This is, as you of course know, the design upon which our British Museum library is now conducted, and it is impossible to exaggerate the services which it yields to literature and human knowledge, however imperfect the library still is.

It would be no more than we might fairly expect from the wealth, intellect, and energy of America that it should ultimately create at least one library equaling or surpassing our national one, but I am aware it must be a work of time.

You may, perhaps, think these remarks somewhat superfluous, but I make them because I have a strong opinion that there ought to be in every part of the world great repositories, where the literature of the past and present may be put, as far as possible, beyond the risk of destruction, and handed down for the use of future generations. We cannot tell what will be of most interest to future ages, and therefore, the best way is to preserve as much as possible.

PRIZE-QUESTIONS OF SCIENTIFIC SOCIETIES.

SOCIETY FOR THE ENCOURAGEMENT OF SCIENCE, LITERATURE AND ART, DUNKIRK, FRANCE.

Programme of subjects for competition, 1873.

A gold medal for the best work on each of the following subjects:

SCIENCE.

Alcohol: its effects on the animal economy. What are the dangerous principles left in the manufacture of alcohol from beets?

Investigate the means of neutralizing the injurious effects produced on the mind and the moral nature of man.

The gold medal will have the value of 300 francs.

LITERATURE—HISTORY.

Biography of the Flemish painter Jean de Reyn, born at Dunkirk in the seventeenth century. Give a systematic catalogue of his works.

The gold medal will have a value of 200 francs.

ART—PAINTING.

A sketch in oil, on a canvas called No. 15, being 65 centimeters (26 inches) long and 54 centimeters (21 inches) broad, the subject of which, history, landscape, *genre*, &c., is left to the choice of the contestants. The canvas not to be framed.

The gold medal will have a maximum value of 300 francs.

The successful competitor will be allowed to choose between the medal and the sum which it represents.

NOTE.—The society will also offer one or more honorable mentions inscribed upon medals of enamel, silver, or bronze.

All the sketches except the one which obtains the prize will be returned to the artists after the award.

To secure the *incognito* imposed upon and guaranteed to competitors who do not obtain a prize, and at the same time to enable them to receive their works after the award has been made, the society requests them to send, with their sketches and the sealed envelopes containing their full names, &c., an address to which the articles can be sent. The works sent should be directed (free) to the general secretary of the Dunkirk society before October 1, 1873. They must not be signed, but should

have a private mark, repeated on a sealed note giving the full name, profession, and residence of the authors, who shall certify that their works are unpublished and have not been offered in competition before. This note will only be opened in case the work merits a prize or honorable mention; otherwise it will be burned during the meeting.

Authors who make themselves known in advance, in any way whatever, will be excluded from competing. Works sent for competition will become the property of the society, but authors may obtain copies at their expense. The candidate who, having been successful at one of the five preceding awards, shall obtain the first rank will only be entitled to a commemorative medal.* In this case an honorable mention, inscribed on a silver medal, may be granted to the work ranking second. The contestant who is entitled to several prizes for one of the subjects open to competition will only receive the highest medal.

The society reserves the right of awarding medals to those who have presented gifts or unpublished memoirs which, though not invited by the programme, shall appear to merit distinction.

For further information address the general secretary of the society.

A. BONVARLET, *President.*

L. MORDACQ, *Secretary.*

SOCIETY OF SCIENCE, ART AND LITERATURE, HAINAUT, FRANCE.

Programme for 1873.

PART I.

LITERATURE.*

I. Eulogy on Francis Fetis.
II. The same in verse.
III. A poem on a subject from Belgian history.
IV. A poem on a subject from real life.

BIOGRAPHY.

VI. Biography of a citizen of Hainaut distinguished by his talents or the services he has rendered.

FINE ARTS—ARCHITECTURE.

VII. Describe the architecture of the monuments and private houses erected in the city of Mons during the last two centuries.

HISTORY.

VIII. Write the history of any of the old cities of Hainaut, except Soignies, Péruwels, and Saint-Ghislain.

IX. Give the history of coal-mining in Hainaut.

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* This rule only applies to the contestants for the scientific prize.

EDUCATION.

X. Give a critical review of the laws in regard to education.

SCIENCE—GEOLOGY.

XI. A description of the Post-Tertiary rocks of Hainaut, situated on the left bank of the Sambre.

XII. Give a correct list of the useful materials in the Tertiary and Post-Tertiary deposits of Hainaut, with their industrial and agricultural applications, and mentioning their locations and their economical uses.

XIII. Give the history of the insects most injurious to agriculture, pointing out the effectual, cheap, and ready methods of destroying them, or at least of checking their ravages.

MEDICINE.

XIV. Write a practical and popular manual on the first steps to be taken in case of sickness or accident. The author must strive to overthrow wide-spread prejudices.

XV. Compare the advantages and disadvantages of the treatment of sick paupers in hospitals of different kinds and at their homes.

AGRICULTURE AND HORTICULTURE.

XVI. Examine the natural or physical causes of the degeneracy of seeds in cultivated plants.

XVII. The selection of seed and the good results which will result from it in agriculture and kitchen-gardening.

PART II.

QUESTIONS PROPOSED.

a. By the government:

XVIII. A critical discussion of the works of J. F. Le Poivre, geometrician, of Mons.

XIX. Discuss fully the subject of the treatment of iron-ore on a large scale simply with coal.

b. By the standing committee of the provincial council:

XX. Point out and describe, in a general way, the location, the character, and the treatment of the different iron-ores worked in the province of Hainaut.

Mention the geological indications which may serve to guide in the search for the deposits of iron-ore which may exist in the province of Hainaut, and discuss their value.

XXI. Point out and describe the cheapest chemical reagents and the most simple methods for precipitating all the materials dissolved in the waste-water from sugar, lamp-black, and chemical manufactories, and from dye-houses, so that it will only be necessary to filter the water thus

treated in order to obtain it limpid and free from any organic or inorganic substance in solution.

The prize for each of these subjects is a gold medal.

Memoirs should be sent free, before December 31, 1873, to the president, 21 rue Compagnons, Mons.

Competitors must not sign their articles, but only put on them a private mark, also placed on a sealed note containing their name and address.

From the competition will be excluded: 1. Active members of the society; 2. Those who make themselves known in any way whatever, as well as those who send their papers after the appointed time, or whose works have been already presented to other academies.

The society will retain the manuscripts addressed to it; but authors, whose works merit it, may obtain copies at their own expense.

Announced at the session in Mons, March 14, 1873.

A. HOUZEAU DE LEHAIE,
General Secretary.

SOCIETY OF SCIENCE, LITERATURE AND ART, HAINAUT FRANCE.

Programme for 1874.

PART I.

LITERATURE.

1. A poem on a subject from Belgian history.
2. A poem on a modern subject.
3. A novel in prose.

BIOGRAPHY.

4. Life of a citizen of Hainaut distinguished for his talents or the services he has rendered.

FINE ARTS—ARCHITECTURE.

5. The architecture of the monuments and private houses of Mons in the last two centuries.

HISTORY.

6. The history of one of the old cities of Hainaut, excepting Soignies, Péruwels, and Saint-Ghislain.
7. The history of coal-mining in Hainaut.

EDUCATION.

8. A critical review of our laws and regulations in regard to primary instruction.
9. The same in regard to intermediate education.
10. The same in regard to higher education.

SCIENCE—GEOLOGY.

11. Show the present condition of our knowledge of the Quarternary formations situated on the right bank of the Sambre.

12. Give a precise account of the materials in the Tertiary and Quarternary formations of Hainaut which may be made useful in agriculture and the arts, specifying their location and their economic applications.

MEDICINE.

13. Compare the advantages and inconveniences of the treatment of sick paupers in hospitals of different systems and at their homes.

AGRICULTURE AND HORTICULTURE.

14. Investigate the natural or physical causes of degeneration in cultivated plants.

15. Investigate and discuss the useful effect of various artificial or chemical manures according to the soil or the system of cultivation.

16. How does the *cuscuta* enter into clover? By what means may its entrance be prevented? How can it be driven out of an affected plant?

17. The selection of seeds and the advantageous results which it will produce in agriculture and market-gardening.

PART II.

QUESTIONS PROPOSED:

a. By the government:

18. A systematic review of the works of J. F. Le Poivre, geometrician, of Mons.

19. Give a complete account of the descent and ascent of workmen in deep mines. Under what conditions should it be conducted in order to insure the lives of the men?

b. By the standing committee of the provincial council:

20. Give a general account of the position, character and treatment of the several iron-ores worked in the province of Hainaut.

Specify the topographical features which would lead to the discovery of the deposits of iron-ore which may exist in the province of Hainaut and discuss their value.

Give an account of the cheapest chemical reagents and the simplest manipulations for precipitating all the substances dissolved in the waste-water from sugar-factories, lampblack-factories, chemical works, and dye-houses, so that it will be sufficient to filter the water so treated, in order to obtain it limpid and free from any organic or inorganic substance in solution.

The prize for each of these subjects is a gold medal.

Memoirs should be sent post free before December 31, 1874, directed to the president of the society, 21 rue des Compagnons, at Mons.

Competitors must not sign their papers, but add a private mark, given also on a sealed envelope containing their name and address.

There will be excluded from competing: 1. Active members of the society; 2d. Those who make themselves known in any way, or who send their papers after the proper time, or whose works have been previously communicated to other academies.

The society will retain all manuscripts addressed to it; but authors, whose papers justify it, may obtain copies at their expense.

Adopted at Mons, session of March 5, 1874.

A. HOUZEAU DE LEHAIE,
General Secretary.

ROYAL INSTITUTE FOR THE ENCOURAGEMENT OF THE NATURAL, ECONOMICAL AND TECHNOLOGICAL SCIENCES, NAPLES, ITALY.

Programme for the year 1874.

I.

The following proposition, which the institute submits to the study of the men of learning in Italy and other countries, is of undisputed utility. For what a miserable spectacle is presented by those to whom nature has been only a step-mother, having deprived them of sight, hearing, and speech. How much intellectual power, how much human labor, is lost in those born deaf and dumb or blind. It is well known that many illustrious men of the most civilized nations have given their life-work in behalf of our fellow-men who are condemned to a deplorable inaction for want of the principal organs of labor. Yet, although much has been accomplished already, there is much still to be done before the goal is reached.

The institute, therefore, hopes that the number of benefactors will be increased by the discussion of the following proposition:

"Give the history and a critical analysis of all the means of instruction, physical and mechanical, which have been proposed up to the present time for those born blind or deaf and dumb, for the purpose of directing future efforts to the most efficacious and the best adapted means, and thus contributing to the discovery of more appropriate agencies for the furtherance of an object of so much social benevolence and of scientific interest."

The subject of the instruction of the blind must be treated thus: First, the methods for teaching literature and sciences; secondly, those for teaching music; thirdly, those for teaching arts and trades.

The methods for the instruction of the deaf and dumb must be divided principally into, first, those which teach them to write; secondly, those which teach them to speak.

II.

The industry of œnology in Italy does not interest the Italians alone The freedom allowed to commerce at present has rendered people of different nations a part of one and the same family. The industrial progress of one nation redounds to the benefit of the whole human race. The institute, therefore, doubts not that besides the Italian œnologists, those also of other nations will study the following subject:

"To expound the principal economical and technical criteria most advantageous in the manufacture of wines in Italy, especially with regard to their preservation and exportation, distinguishing, if necessary, those proposed for different sections of Italy in which the œnological industry can be successfully cultivated."

In order to prevent any misunderstanding, it may not be out of place to state here that the institute does not expect from the competitors a manual, and much less a regular treatise on the manufacture of wines in Italy. They will be expected to give their attention mostly to the qualities which science indicates as essential to the preservation and exportation of wines with safety, and to state how far Italian manufacturers are governed by such indications of science. The competitors will not fail, also, to take carefully into consideration the various types of wines produced in Italy, to suggest what science, the œnologic art, and public economy teach, and, if necessary, what legislative enactments are required in order to produce safely and speedily wines which will resist the injuries of time, and which will be fit to export to distant countries.

CONDITIONS OF THE ABOVE COMPETITIONS.

1. Competition on the above subjects will be open to all except the regular members of the Royal Institute.
2. The competing manuscripts must be in Italian.
3. Such manuscripts must be presented—those in regard to the first subject, on the 30th day of October, 1874; and those answering the second, on the 31st day of August, 1875. The above manuscripts should be addressed to the permanent secretary of the Royal Institute. These conditions are indispensable.
4. Every manuscript should be distinguished by a motto, which must be repeated upon a sealed envelope containing the full name, native place, and address of the author. The authors who in any way make themselves publicly known will be excluded from the competition.
5. The envelopes of the articles which will receive a premium, and of those which will be favorably mentioned, will be opened in a formal meeting of the institute, and the names of the authors will be published. The envelopes of the unsuccessful articles will be burned; the articles themselves, however, will be deposited in the archives of the institute.
6. To the author of the article which, in the judgment of the insti-

tute, answers all the requirements of the first question, a premium will be given of 1,000 lire ($186) and the large gold or silver medal of the academy, according as the institute considers the production as deserving more or less distinction. To the author of the article which answers all the requirements of the second question, a premium of 1,500 lire ($279) will be awarded and also a gold or silver medal. The articles receiving premiums and perhaps those also deserving honorable mention will form part of the published acts of the academy.

7. Each author whose article is published in the acts of the academy will receive free, with an appropriate frontispiece, one hundred copies of the same. Besides this, the author, after the publication of the acts, will enjoy the copyright of his work.

8. The institute will not refuse those articles which answer only one part of the above questions; but, in such a case, it reserves to itself the right of awarding the corresponding premium or not, as it may see fit; as it also reserves to itself the right of conferring the large academical medal for those articles which may be honorably mentioned.

The premiums which the institute proposes are not of much material value, but it is evident that those who will attend to the solution of the above propositions will find in their work, by reason of the benefit which it will produce, ample and noble reward.

Naples, Royal Institute, February 6, 1874.

F. TRINCHERA,
President.
F. DEL GIUDICE,
Perpetual Secretary.

ROYAL ACADEMY OF SCIENCE, LITERATURE AND THE FINE ARTS, BRUSSELS, BELGIUM.

CLASS OF FINE ARTS.

List of prizes for 1874.

LITERARY SUBJECTS.

First subject.—The history of sculpture in Belgium in the seventeenth and eighteenth centuries.

Second subject.—The history and bibliography of musical typography in the Low Countries, and especially in the provinces now constituting Belgium.

The values of the gold medals offered as prizes for papers on these subjects are 1,000 francs ($200) for the first and 800 francs ($160) for the second.

Papers sent for competition should be legibly written, and may be in French, Flemish, or Latin. They should be sent, post free, to the permanent secretary of the academy before June 1, 1874.

Authors must not append their names to their papers; they should merely add a private mark, given also on a sealed note inclosing their names and addresses. If this regulation be not complied with, the prizes will not be awarded.

Papers sent after the prescribed time, or those of which the authors make themselves known in any manner whatever, will be excluded from competition.

The academy insists upon the greatest exactness in quotations; it requires, therefore, that competitors specify the editions and the pages of the works referred to in the papers presented for its decision.

Manuscript-illustrations alone will be accepted. The academy reserves the right to publish prize-essays. The authors of papers published in the collections will be entitled to one hundred copies for their own use. They may also obtain additional copies by paying the printer four centimes (one cent) a sheet.

The academy deems it necessary to remind competitors that papers which have been submitted to its judgment are retained in its archives as its property. Authors may at any time obtain copies at their expense by addressing the permanent secretary to that effect.

SUBJECTS IN APPLIED ART.

Painting.

A design for a painting $1^m.50$ (5 feet) high and $4^m.50$ (15 feet) broad for a frieze 5^m (16 feet) above the floor. This painting is intended for a hall in a hospital, and should be on the subject, "Give food to the hungry and drink to the thirsty." The design submitted should be made one-half the above dimensions, namely: $0^m.75$ high and $2^m.25$ broad.

A prize of 1,000 francs ($200) will be awarded to the successful competitor. A draught of the design will be kept in the academy. Paintings intended for competition must be sent to the secretary of the academy before September 1, 1874.

Engraving.

A prize of 600 francs ($120) will be awarded to the maker of the best engraving executed in Belgium, during the period from January 1, 1872, to January 1, 1874, after the design of an old or recent master of the Flemish school.

Competitors should submit a copy of their work before September 1, 1874.

General regulations relative to this competition.—Competitors must not inscribe their names on their productions; they must only affix a mark, given also on a sealed note containing their name and address. The prizes will not be awarded if this regulation be not complied with.

Works sent after the expiration of the prescribed time, or those of which the artist's name is made known in any way whatever, will be excluded from competition.

The committee have selected for the prize-competition in 1876 the following literary subject: "Trace the origin of the Belgian school of music, and determine to what period the old masters of that school followed the French and English musicians of the twelfth and thirteenth centuries."

A prize of 1,000 francs will be awarded for the solution of this question.

Brussels, session of November 6, 1872.

For the department of fine arts,

A. QUETELET,
Permanent Secretary.

ROYAL ACADEMY OF SCIENCE, LITERATURE AND FINE ARTS, BRUSSELS, BELGIUM.

CLASS OF SCIENCE.

Prize-questions for 1874.

FIRST QUESTION.

To perfect, in some important particular, either in its principles or in its applications, the theory of the functions of an imaginary variable.

SECOND QUESTION.

To give a complete discussion of the question of the temperature of space, based upon experiments, observation, and calculation, giving the reason for the choice made among the different temperatures which have been ascribed to it.

We deem it necessary to explain to the competitors that the question, in its most general terms, refers to the determination of the absolute zero, definitely fixed at $-272^{\circ}.85$ C.; ($-459^{\circ}13$ F.) but a historical and analytical discussion of the investigations undertaken previously to 1820, for the purpose of deciding this question, will prove of real scientific interest. Attention is particularly directed to the investigations made at the close of the eighteenth century and the commencement of the nineteenth, among others those of Black, Irvine, Crawford, Gadolin, Kirwan, Lavoisier, Lavoisier and Laplace, Dalton, Desormes and Clement, Gay Lussac, &c. Mention is also made of the temperature of -160°, C. (-256° F.) given by Person, according to his formula, which connects the latent heat of fusion with specific heat; this number representing the absolute zero. As it agrees very nearly with that given by Pouillet, it will be important to discover its signification, its sense, or its exact physical value.

THIRD QUESTION.

To give a complete theoretical and experimental investigation of the absolute specific heat of simple and compound bodies.

FOURTH QUESTION.

To give the result of new experiments on uric acid and its derivatives, principally with regard to their chemical structure and their synthesis.

FIFTH QUESTION.

The polymorphism of fungi attracts more and more attention from botanists and physiologists. It seems even to furnish new elements for the solution of the problem of life in general.

Required:

1. A succinct critical review of the known observations relative to the polymorphism of *Mucedines*.

2. The exact determination—applying only to a single species—of the part which belongs at first to the proper nature of the vegetable (to its specific energy) and then to the exterior conditions of its development.

3. The positive proof, or the satisfactory disproof, of the fact that ferment-molds (*Micrococcus*, *Zoöglœa*, *Palmella*, *Leptothrix*, *Arthrococcus*, *Mycoderma*, &c.) can under any circumstances whatever transform themselves into fungi of a higher order.

SIXTH QUESTION.

To describe, especially in regard to their composition, the Plutonic rocks, or those considered as such, of Belgium and French Ardennes.

The prize for the first, the fourth, and the fifth questions will be a gold medal of the value of 600 francs; the prize for the sixth will be of the value of 800 francs; and the prize for the second and third will be of the value of 1,000 francs.

The authors of the memoirs inserted in the reports of the academy will be entitled to one hundred copies of their papers. They will also have the privilege of obtaining a larger number by paying four centimes a sheet.

Manuscripts should be written legibly, should be in Latin, French, or Flemish, and addressed, postage prepaid, to Ad. Quetelet, permanent secretary, before August 1, 1874.

The academy requires the greatest exactness in citations; authors must, therefore, be particular to mention the editions and the pages of the works cited. Manuscript-illustrations only will be allowed.

Authors must not put their names on their papers, but only a device, which must be repeated on a sealed envelope containing their names and addresses. Papers sent after the prescribed time, or those indicating the author's names in any way, will be excluded from competition.

The academy deems it necessary to state to the contestants that, after papers have been submitted to its judgment, they are placed in

its archives as its property. Authors may always obtain copies at their expense by addressing the permanent secretary.

Brussels, session of February 1, 1873.

For the class of science,

AD. QUETELET,
Permanent Secretary.

ROYAL ACADEMY OF SCIENCE, LITERATURE, AND FINE ARTS, BRUSSELS, BELGIUM.

CLASS OF SCIENCE.

Prize-questions for 1875.

FIRST QUESTION.

Examine and discuss, in the light of recent experiments, the disturbing causes which affect the determination of the electro-motive force and the internal resistance of an element of the electric battery; give the numerical determination of these two quantities in some of the principal batteries.

SECOND QUESTION.

Give a summary of the facts discovered on the influence of heat upon the development of phanerogamous vegetation, particularly in regard to the periodic phenomena of vegetation, and, for this purpose, discuss the value of the dynamic effect of solar heat on the growth of plants.

THIRD QUESTION.

Give the results of new researches in regard to the embryonic development of *Tunicata.*

FOURTH QUESTION.

State the results of new researches to establish the composition and the mutual relations of the albuminoid substances.

FIFTH QUESTION.

Give a description of the coal-measures of the Liége basin.

The values of the gold medals to be awarded as prizes are 1,000 francs for the fourth and fifth questions, and the former value, 600 francs, for the first, second, and third.

Authors of the papers inserted in the collections of the academy will be entitled to one hundred copies of their works. They may also obtain a larger number by paying the printer for the same at the rate of 4 centimes a leaf.

Manuscripts should be legibly written, composed in Latin, French,

or Flemish, and addressed, post free, to Ad. Quetelet, permanent secretary, before August 1, 1875.

The academy insists upon the utmost accuracy in quotations; authors should, therefore, be particular to specify the editions and pages of the works cited. Only manuscript illustrations will be received.

Authors should not sign their names on their papers, but merely affix a private mark, repeated on a sealed note containing their names and addresses. Papers sent after the prescribed time, or those the writers of which make themselves known in any way whatever, will be excluded from competition.

The academy deems it necessary to repeat to competitors that as soon as papers have been submitted for its examination they are placed in its archives, as having become its property. Authors may, at any time, obtain copies, at their own expense, by addressing, to that effect, the permanent secretary.

Brussels, session of January 10, 1874.

For the class of science,

AD. QUETELET,
Permanent Secretary.

SOCIETY OF SCIENCES, HARLEM, HOLLAND.

PROGRAMME FOR THE YEAR 1874.

The Holland Society of Sciences held its one hundred and twenty-second general meeting May 16, 1874.

Director Jhr. G. F. van Tets, recently appointed president of the society in place of the late Baron F. W. van Styrum, opened the meeting by an address, in which he honored the memory of his predecessor and recalled the many services rendered by him to the society in his capacity as director since 1835 and as president since 1867. The deceased also performed in 1838 and 1839 the duties of secretary of the society after the death of the illustrious van Marum.

In addition to the loss of its president, the society has also had to mourn, in the course of the past year, that of several of its directors and members, namely: J. P. A. van Wickevoort Crommelin, A. F. H. Hoffman, and G. L. J. van der Hucht, directors; H. C. van Hall, G. C. B. Suringar, and M. Hoek, national members; L. J. R. Agassiz of Boston, A. A. de la Rive of Geneva, and L. A. J. Quetelet of Brussels, foreign members.

The president informed the meeting that Jhr. Q. Hoeufft of Harlem, P. Langerhuizen of Huizen, and D. Visser van Hazerswonde of Amsterdam had just been appointed directors of the society.

Since the last general meeting, the society has published the following works:

Archives néerlandaises des sciences exactes et naturelles, numbers 3, 4, and 5 of volume 8, and numbers 1 and 2 of volume 9.

Natuurkundige Verhandelingen, 4to, 3d series, parts 1 and 2 of volume 2, containing two memoirs presented by Dr. Bleeker, namely:

First. Révision des espèces indo-archipélagiques du groupe des *Apogonini*.

Secondly. Révision des espèces d'*Ambassis* et de *Parambassis* de l'Inde archipélagique.

It has also presented, through J. H. van den Broek, the report of the commission appointed by the directors to examine the claims of the candidates for the Huyghens large gold medal. This medal should be awarded, according to the terms of the grant, to the Netherland or foreign scientist whose researches, discoveries, or inventions in the course of the last twenty years should be deemed to have contributed in a marked degree to the progress of chemistry.

Agreeably to the recommendation of the commission, composed of D. de Haan, P. J. van Kerchhoff, C. H. van Ankhum, J. H. van den Broek, A. C. Oudemans, J. M. van Bemmelen, and E. H. von Baumhauer, the society decided that the Huyghens medal should be awarded this year to Auguste Kekulé, professor at Bonn, for his interesting researches into the constitution of the carbon-compounds.

Among the subjects for prize-discussions in 1872 were the following:

"Find a satisfactory method of determining the temperature, humidity, and density of the atmosphere at a considerable height above the surface of the earth; this method should provide for the automatic registry of the observations, or at least their frequent repetition."

In reply to this question, the society received a memoir written in Italian, and bearing the motto *Provando e riprovando*. Following the advice of the commission which had been charged with the examination of the work, the assembly decided that it was not entitled to the prize.

In conclusion, the assembly proceeded to the election of new members of the society. This election resulted as follows:

NATIONAL MEMBERS.

C. G. Cobet, professor of philosophy and literature at Leyden.

Th. W. Engelmann, professor of medicine at Utrecht.

F. W. van Eeden, of Harlem, secretary of the Netherland Society for the Encouragement of Industry.

FOREIGN MEMBERS.

A. Kekulé, of Bonn.

M. P. E. Berthelot, of Paris.

A. Secchi, of Rome.

L. Pasteur, of Paris.

The society has proposed, at this meeting, the following subjects for

prize-essays, the period for the reception of essays terminating on the 1st of January, 1876:

I. Give the results of exact investigations on the dissolving effect of water and water charged with carbonic acid on gypsum, limestone, and dolomite at different temperatures and under different pressures, and in cases where sea-salt and other abundant soluble salts are present.

II. Give the results of exact determinations of the dissolving effect of water and of water charged with carbonic acid on silica and the most common natural silicates at different temperatures and under different pressures and in cases where sea-salt and other widely-diffused soluble salts are also present.

III. Give the results of a new study of the structure of the viscera of mammals, especially in regard to the epithelial covering in the different portions of the renal tubes.

IV. It appears from recent investigations that the peptones of many albuminoid materials are composed of substances now known in part and in part unknown. Required a critical review of these investigations, supplemented by personal researches on the same subject.

V. Give the exact determination in Weber's units of the resistance of a column of mercury one meter (39 inches) long, and a square millimeter ($\frac{1}{7}$ square inch) in section at 0°, (32 F.) All the steps relative to this determination should be given to as complete an extent as possible.

VI. To increase by means of careful experiments our knowledge of the relation between the two kinds of electrical units, electro-magnetic units and electro-static units. All the steps in this determination should be presented as fully as possible.

VII. Required new experiments in regard to the influence of pressure on chemical action.

The society repeats the following questions, the period of competition for which expires January 1, 1875:

I. Give for ten varieties of glass of known chemical composition, 1st, the co-efficients of expansion between 32° and (at most) 212° F., noting the influence of temper and the state of tension; 2d, the co-efficients of elasticity, with exact reports of temperature; 3d, the indices of refraction for at least ten points taken over the entire extent of the spectrum; also carefully noting the temperature. *The gold medal and 150 florins.*

II. Does the co-efficient of expansion of steel vary with the degree of temper; and can empirical laws be determined in regard to the connection of these two elements?

III. Do experiments show a connection between the diffusion of liquids separated by porous partitions and other phenomena, such as capillarity, &c.?

IV. Determine the co-efficient of expansion of at least three liquids of simple composition, following the method by which the absolute expansion of mercury has been determined.

N. B.—The temperatures in all the preceding cases should be reduced, as far as possible, to that of a thermometer in air.

V. Required researches on the origin of organs of sense, especially of the organ of sight, among some of the inferior animals; this origin being considered, as far as possible, in connection with the conditions under which the animal is found, and the exterior influences to which it is exposed.

VI. In terrestrial magnetism, what periods are known with sufficient exactness, and to what point may these periods be confidently associated with other phenomena, cosmical or terrestrial.

VII. Required new experiments and observations concerning the question of learning how the albuminoid substances are formed and displaced in the plant; a historical and critical review of anterior researches should precede this account.

VIII. In proportion as the number of known isomeric substances increases in the domain of organic chemistry, it becomes more desirable that their differences of structure should be harmonized with their physical characters. Therefore, the society requires the exact determination of the co-efficient of expansion, the fusing-point, the boiling-point, the specific heat, the index of refraction, and the specific rotary power of at least twenty organic compounds which are isomeric two by two and the chemical composition of which is known.

IX. The experiments of M. Regnault in regard to the specific heat of some terpins and those of M. Berthelot in regard to diamylene and triamylene show that the specific heat of polymers of a compound may be equal to that of the fundamental materials of which they are formed. The society requires that the investigations should be made as far as possible to cover other combinations having the same relations with each other, in order to decide if the fact observed by Regnault and Berthelot may be raised to the rank of a law or not.

X. Submit to a profound investigation the composition of tetraphenol and its derivatives so as to be enabled to pass judgment on the hypothesis of M. Limpricht concerning the existence of a series of aromatic substances in the stones of fruit composed of four atoms of carbon.

XI. Required a critical review of the observations and experiments concerning the existence of bacteries in contagious diseases of men and other mammals, followed by original researches on the same question made on one or more of these contagious diseases. The nature of foreign organisms should be exactly determined with figures; and the author should determine by experiment to what point the contagious character of the disease is confined to the presence of bacteries.

XII. Of late years the mode of growth of bones has been studied on a large scale by several scientists, who have obtained very contradictory results. The society requires a work on this subject in which the

author will support his opinion by his own researches and compare them with those of other experimenters.

XIII. The progress of science has brought some sort of confusion in the determination of several species of plants and even in the definition of the species. It is observed that most of the species formerly recognized include diverse forms which some call races or varieties, and others species. The works already written in regard to *Rubus*, *Hieracium*, *Mentha*, *Salix*, &c., are important, but they have the fault of being confined to species very closely related to each other, consequently very confused. Besides, the forms studied have usually been confined to those of a certain country, as the *Rubus* of England or Germany, instead of comparing all the forms of a certain species of *Rubus*. Consequently, there is required a profound study of some of Linnæus's species, selected from those which present more or less diverse forms, paying particular attention to the following particulars:

First. The species should be wild plants, at least ten and at most twenty in number, belonging to at least two natural families, and growing in well-explored countries, such as Europe, the United States, &c.

Secondly. The author should endeavor to describe and classify all the forms which are more or less distinct and more or less hereditary that enter into the Linnæan species, taking care to specify their place of growth, their rank, and to tell if the observations were made from living plants, from dried specimens, or if they are described from books.

Thirdly. Their mode of fecundation should be examined, and the point to which certain forms may be attributed to crossing determined.

Fourthly. The amount of hereditary influence on forms should be determined by experiment, at least in a certain number of cases, and in the case of woody species during at least two generations.

Fifthly. For woody species it will be necessary to determine the possibility or impossibility of grafting on each other forms belonging to the same kind.

Sixthly. The classification of forms in species, races, or subspecies, varieties, subvarieties, variations, subvariations, and other subdivisions which may be necessary, should be based at the same time on exterior forms and on the closest affinities shown by fecundation and grafting.

January 1, 1878.

Our knowledge is still more limited in regard to the quantity of mud and other material brought by rivers to the Netherlands, the places where these matters are most frequently deposited, and the circumstances which influence their transport and their deposit. We wish to see these points cleared up for one or several of the rivers of our country, through observations or experiments continued during many years.

The society recommends contestants to omit in their papers everything which has not an immediate connection with the question proposed. The society desires to find clearness and precision in everything

submitted to it, and the propositions demonstrated clearly separated from vague considerations and unestablished facts.

It repeats also that any memoir written in the author's hand will not be received; and that even when a medal has been awarded, the presentation will not be made if the author's hand has been recognized in the mean time in the selected essay. The sealed envelopes sent with unapproved essays will be destroyed unopened, unless it be discovered that the work presented is only a copy from printed works, in which case the author's name will be divulged.

Every member of the society will be allowed to take part in the competition on condition that his paper as well as the accompanying envelope be signed with the letter L.

The prize offered for a satisfactory answer to each of the questions proposed consists, at the pleasure of the author, either of a gold medal, struck from the ordinary die of the society and bearing the name of the author and the date, or a sum of 150 florins. A supplementary award of 150 florins may be made if the memoir be judged worthy.

The competitor who receives the prize will not be allowed to print the prize-essay, either separately or in any other work, without obtaining for it the express permission of the society.

The memoirs, legibly written in Dutch, French, Latin, English, Italian, or German, (but not in German characters,) should be accompanied by a sealed envelope containing the name of the author, and sent free to the secretary of the society, Professor E. H. von Baumhauer, Harlem.

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